Heroes of Science

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BOOK I

HEROES OF PURE SCIENCE

Every one has his heroes. Each age and every nation has them. They are those men whom we admire so much that if our dreams came true, we should be like them.

Now choosing a hero is a serious matter. One may almost say, "Like hero, like worshiper." Therefore we must choose carefully. We must decide beforehand what our hero will be like. Shall he be gentle or ruthless, generous or selfish? Shall he be a master at spreading fear or happiness? Napoleon was so great a fighter that thousands of families never forgot him in their curses. Shall he be one of our heroes?

If not, who shall be? Who are the men we ought to follow? One thing is certain: our heroes must be fighters. But on what battlefield and for what cause?

NICHOLAS COPERNICUS
(1473–1543)

A New Heaven and a New Earth

I

When man first looked about him, at the beginning of time, the mystery of his world filled him with strange emotion. The earth, with its fruits and grain, gladdened him for the strength it gave him. But as he looked overhead, what he saw frightened him. That vast impenetrable space — the home of the blinding lightning and thunder — what might it send down on him? Was it friend or enemy? So it was quite natural that when the heavens were black and charged with storm, he should say it was angry. For he himself had felt anger lowering on his brow. But when the sky beamed blue and softly luminous, how gently it seemed to smile!

Nighttime, those twinkling points of light, the stars, that shone forth every evening only to vanish again in the dawn, soothed him with a peaceful glow. He believed that each cluster of stars or, as it is called, each constellation, was a spirit watching over earthly affairs. He thought so because it looked like an animal or some familiar object. And he named the constellations: the Little Bear and Great Bear, the Lion, the Swan, the Ram, the Bull, the Great Dog, and the Little Dog. It seemed to him, too, that the stars were perhaps nails fixed in the firmament, or fiery plates of gold. But how big these plates were and how far away, he was not certain.

As the shepherd sat on the hillside, near his browsing

flock, he scanned the sky anxiously and mused long on its secret. Night and day, summer and winter, the moving heavens and the solid earth — these were the riddles that nature put to him. For ages he was puzzled, but at length he answered the riddles triumphantly.

"I have it! The universe is a box, well . . . a sort of pie dish with a lid on it."

That was the general idea. Now with great satisfaction, he filled in the details.

"The earth is the dish, or the floor of the box. The sky is the top or lid."

There was one problem. At home the pie dish rests on a table. What does the Big Pie Dish rest on? That was not a hard question, said our philosopher. The Big Pie Dish rests on the Big Table, or on the shoulders of Atlas, or on the back of a giant tortoise.

"But," objected the clever pupils, "what does Atlas or the tortoise rest on?"

That might have been a hard question for some, but not for the hungry philosophers. "Everything floats in a great sea of milk," they answered, "or, if not milk, something else good to drink."

The explanation was at least appetizing and homely. And then, to complete the picture, the puzzle of day and night was solved by the early scientists.

"When you make a bonfire," they explained, "a spark here and there flits up, a tongue of flame shoots out at this part of the heap, another at that part. All these bits of fire finally join in one mighty blaze. And later when the fire dies down, what do you see? Here a glowing ember, there a flicker.

"So with our heavenly fire. At dawn the earth flashes points of fire. These rise, come together, and form the sun. At twilight the fire of the sun goes out, scatters, and forms the moon and stars."

Some wise people, who were not so enthusiastic over food and cooking, laughed at all this. "Nonsense!" they jeered. "Anybody with brains can see at once that the universe is a cage, and the earth a huge bird inside. Mecca is the head, of course. Persia and India are one of the wings. Africa is the tail. . . . On the rod of the cage the sun and moon move like fishes, by day from east to west. At night, they steal around the edge back to their original positions."

That was possible. Who knew the truth? They shrugged their shoulders. On two matters, however, both the Pie-Dish scientists and the Bird scientists agreed. First, that mankind lived in the center of the universe and therefore the vault of heaven turned around him. Second, that the fate of man was written in the sky, if you could only read the language.

"You may thank your lucky stars that you are safe and well," said one to the other ominously.

"My stars!" was the reply. "But I did have a narrow escape!"

Should anyone have to go on a journey or transact a piece of business, he first consulted a seer, an astrologer, who fathomed the heavens and told his client the advice of the stars.

There was one tremendous fault with all this. Whether you were a Pie-Dish believer or a Bird believer, you could never predict when the sun would rise and set to-morrow, or where a particular star would be next year.

II

About eighteen hundred years ago there lived a man named Ptolemy who changed all these notions and thus ruled the world of science, winning for himself the title, "Prince of Astronomers."

"I agree," said he, "that the earth is the center of all things and that the stars write the story of our fate in the sky."

But that was not enough to say, realized Ptolemy. He saw that during part of the year, the sun rose a little earlier every day and set a little later; then for the rest of the year, it rose a little later, and set a little earlier. He saw that the few stars which moved — the wanderers, which he called "planets" — moved in certain orderly ways. And he realized that the universe was a great system of laws. But what were these laws?

"We, on earth," said Ptolemy in his book called "Almagest", "are in the center of a vast globe. The firmament above us is solid and studded with stars. And like a wheel it turns round the earth. But this is very strange; the sun, moon, and each of the planets, all have their own peculiar paths around the earth."

Of course, he could not see these paths with his eyes. He calculated them. "If my picture of the heavens is true, then I can tell you where any planet will be at any moment in the future." And he made up tables of figures.

The wonderful thing about Ptolemy's tables was that they almost worked. The planets were always somewhere near the place that Ptolemy's tables foretold they would be; somewhere near, though not quite on the spot. But the difference bothered nobody. For once, the mystery of the heavens was clearing up. And Ptolemy was the man who had shown that the universe was not a mystery. No wonder everybody had faith in Ptolemy, and refused to believe anybody else.

So thirteen centuries went by, and in the schools, Ptolemy's word was unquestioned. But at length, in 1473, in Thorn, a small Prussian town belonging to Poland, was born one who was to challenge Ptolemy.

Nicholas Copernicus, son of a successful Polish mer-

chant, was the man. At the time Columbus was discovering the New World, Copernicus was studying at the University of Krakow, preparing himself to give the world "a new heaven." He then went to Italy, the center of learning, where he stayed ten years, first as a student, then as a teacher.

His zeal for learning, it seems, knew no bounds. He simply mastered everything: law, medicine, natural science, mathematics. He was a skillful painter, was expert in civics. Upon his return to Poland, he was appointed a member of the Council of German States. He was on one occasion sent on a diplomatic mission to the King of Poland. He also wrote a book on economics, which was greatly admired by the learned. In addition, he was a translator of books from the Greek.

His greatest interest, however, lay in astronomy. But in this study he was extremely handicapped. For there were no telescopes, nor any of the instruments we have to-day for observing the heavens. The few instruments he used, he had to make himself.

"Why do you have to worry about astronomy?" everybody said. "Ptolemy has said the last word on that subject." Nobody gave Copernicus any encouragement. But he needed none, for he had both genius and courage.

He looked long at Ptolemy's picture of the heavens. "Is it not queer," he thought, "that although all the planets move differently and are in different positions and of different sizes, yet they all seem to go around the earth once a day. It is incredible!"

The more he pondered, the more incredible it seemed. One day a strange idea came to him. "If the earth spun around like a top once every day, then the planets would all seem to be turning around the earth once every day. That I can understand."

People laughed at the idea. "The earth moves! You

must be joking, for that is contrary to common sense. If the earth moved, you could feel the motion." But Copernicus knew that if you were sailing on a smooth sea and you looked at the floor of your cabin, you could not detect any motion. Gaze out from the deck at the scenery, and you do see movement. But which is moving? You, or the scenery? Just so, if the earth were moving, the only way Ptolemy could observe it was by looking at the heavens, and then he thought it was the heavens that moved.

"Perhaps the earth does move!"

But the people of "common sense" had another objection.

"If a large body like the earth moved," they said, "it would travel with such speed that if you shot an arrow into the air, the earth would rush past under it before the arrow came down. Or if you took a high jump, the earth would whizz by, leaving you in the air. Since this does not happen, the earth does not move."

But if you are sitting in your cabin, and you drop a penny, will it not fall at your feet? The penny will not be left in the air. It has the same motion as the cabin.

"Surely the earth moves," said Copernicus confidently. "It must, because it solves the problem of motion in the universe so simply."

But the followers of Ptolemy were not so easily convinced. "Absurd!" they insisted. "A moving earth would fly to pieces."

"Why should it?" retorted Copernicus. "Your moving heavens — have the stars dropped out of it?"

Copernicus now used his mathematics. From youth to middle age he worked constantly to prove his theory. Then he wrote his conclusions in a book, which he did not publish until the very end of his life. He might not even then have done so, for he was modest and very shy. His gentle days were spent in ministering to the sick and poor, and he

would have been content to end his days so but for some friends who were ambitious for him and urged him to publish his thoughts on the universe. And fortunate it is for us that they did. Copernicus always thought, "I am not ready yet. I can better my book. I shall wait . . ." And he might have kept on waiting to the end and never given us the book which proved one of the greatest events in the history of the world. It revolutionized our whole thinking.

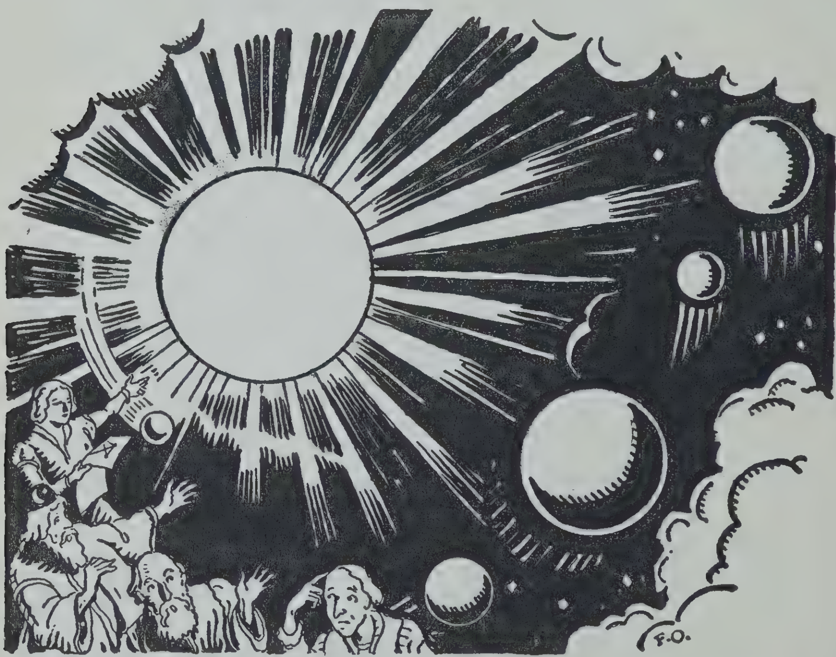
To begin with, Copernicus proved Ptolemy wrong. The earth must move, because only then could the changing positions of all the stars, the seasons of the year, and the changes of night and day all occur simultaneously. The earth, Copernicus showed, is one of the planets. All the planets move around the sun which is the center. "Imagine a series of circles," said Copernicus, "one inside the other. The circles are the paths that the planets follow around the center point — the sun. As for our earth, it spins around like a top once a day, while at the same time, it makes a journey around the sun that lasts a year. The spin gives us day and night. The motion around the sun gives us our seasons."

Wise men indeed saw how accurate, simple, and beautiful Copernicus had made everything, while Ptolemy had complicated the motions of the planets and had been inaccurate in the bargain. And the learned men felt that, although the thought of living on an earth which moves was not a pleasant one, Copernicus was right.

The wonder of this solar system, as we now call it, was grasped slowly. What staggered everybody was the immensity of the universe, as Copernicus pictured it. Before his time the earth was regarded as the largest body in the heavens. We now know that the extent of our universe is terrifying to imagine. We have counted thousands of millions of stars, the light from which takes thousands

of years to reach our eyes. Copernicus himself did not realize how vast the space he had opened up. Beyond the stars even, are heavenly forms which give forth light that, traveling at 186,000 miles a second, takes millions and millions of years to strike the earth. And we know that our sun, which is more than a million times as large as the earth, is only a small star.

Suddenly a scandal arose. "What!" everybody cried. "The earth not the center of the universe! We great men not the center of attraction! We won't believe it. You



"What!" everybody cried. "The earth not the center of the universe!"

say we are of insignificant size, you take us away from our shining center, you make us wabble around the sun, like a moth around a lamp. Outrageous!"

Alas, what could Copernicus do? Truth is truth. He had drawn a new world for an old, a beautiful and precise

one for a cumbrous and inexact one. And still people refused to accept because it hurt their pride.

They were helpless, however, before the mathematics of Copernicus. Yet though they could not challenge him on scientific grounds, they could sneer and play ostrich. "Show us all this," they demanded. "Before we believe it, we want to see with our eyes the picture you have painted."

Ah, this Copernicus could not do. There was no "eye" yet invented strong enough to see the magnificent spectacle. He could prove it, however, and prove it abundantly. But then you had to know a great deal about mathematics to understand the proof. So the world still doubted, and it was left for another hero to convince it that Copernicus was right. Copernicus himself was never to see the wonder in the eyes of his fellow men as they beheld the picture he had painted. Scarcely had he given his consent to the publication of his book when he was stricken with paralysis.

On May 24, 1543, just a few hours before he died, the printer placed the book in his hands. His life's end was the beginning of his immortality.

Years after, when Tycho Brahe, a great astronomer and believer in Copernicus, was given the wooden instruments with which Copernicus had discovered a new heaven, he said: "The earth has not produced such a man for centuries. Copernicus has been able to stop the sun in its path across the sky, and has made the immovable earth move about the sun in a circle. About the earth he caused the moon to turn; he has changed for us the very face of the universe. This Copernicus has dared to do — with these small sticks . . . He has done what was not permitted any other mortal to do since the beginning of the world. . . ."

GALILEO GALILEI

(1564–1642)

The Father of Telescopic Astronomy

I

In the late dusk of an afternoon about three hundred fifty years ago, a young student of medicine at the University of Pisa in Italy was kneeling at prayer in the cathedral there. Galileo Galilei, as the Italian youth was named, or simply Galileo, as he is called to-day, rose at last to go when his glance fell upon the bronze lamp which hung over him in the center of the dim sanctuary.

The attendant had come to light the lamp, and in order to do so more easily had drawn it towards himself. As he released it finally, it began swinging to and fro. Keenly Galileo watched.

And so watching, it struck him that while the swinging grew less and less as it died down, the time of each swing neither diminished nor increased. At least so it seemed. But how could he be sure? There were no watches in those days. How could he measure accurately the length of the time it took the swinging object to make each swing? His heart beat excitedly . . . Ah! The beat in his body! It ticked regularly. For a timepiece he could use his pulse.

So he did. And he found he was right: it took the *same time* for the lamp to make its first largest movement as the last faint tremor. The swing was as regular as the beat of his pulse.

He looked up . . . Something stirred in his mind. He

hurried home at once, and then and there began his famous career of invention which the world forever will celebrate. It had occurred to Galileo that if a pulse beat could time a swinging object, a swinging object could also time a pulse!

The result of this reflection was the first instrument for the use of doctors for taking the pulse of a patient, and the first mechanical device ever made to help a doctor treat the human body. In so many swings of the pulsilogia, for so he called his instrument, a healthy pulse beat a definite number of times, just as nowadays we know that in sixty seconds a healthy pulse beats seventy-two times.

Galileo himself was destined never to use his pulsilogia as a doctor because he was too poor to stay at the university. But he did not mind quitting it. He had for the time become interested in another branch of science, mathematics, and heart and soul he devoted himself to that.

II

When he invented the pulsilogia, Galileo was eighteen, having been born in Pisa, in 1564, in the same year as Shakespeare, and three days before the death of Michelangelo. As a child he distinguished himself by his cleverness in building all kinds of toys.

"He is a born engineer," thought his father.

But no! For when it came to music, which his father, a noted musician, taught him, the young Galileo displayed a finer touch than his teacher on the lute and the organ.

"Ah," thought his delighted father, "he will some day play before princes."

But there again, just when he thought his son's career settled, a new talent began to flower in the youth — painting. And so skillful an artist did Galileo become that no less than the great Jacopo da Empoli himself came to ask him his opinion on pictures.

"Well, then — painting let it be," said the perplexed father.

Yes, but what about the youth's poetry?

"Settle it once for all," cried the bewildered father. "Become a business man, a doctor — anything!"

Galileo decided for himself in this as he did in all things. He had been captivated by the art of mathematics, and he determined to follow science, the language of which is mathematics.

At college, he was dubbed the "Wrangler", because he asked and argued questions which embarrassed his professors. But instead of being encouraged for his cleverness and originality, he was frequently made to suffer for these traits, for learning then, especially in science, was a strange affair. The greatest scientist known up to that time had been an old Greek philosopher, Aristotle by name, who lived about twenty-two hundred years ago. For some not very good reason this Aristotle was then never doubted. If Aristotle said a thing, that thing was settled. Nobody thought of putting *his* word to any test. In fact, if you questioned the word of Aristotle, people became suspicious of you at once. What did you mean, they asked. Were you trying to be different from everybody else?

Aristotle had said, for instance, that if you let drop a ten-pound weight and a one-pound weight at the same time, the ten-pounder would fall ten times as fast as the one-pounder. For eighteen-hundred years everybody believed this, but no one thought of testing it.

No one but Galileo, that is. He was now a professor of mathematics, and announced one day to his students that he had found Aristotle to be mistaken: that two bodies, falling through space at the same time, reached ground at the same time, regardless of their weight. Furthermore he invited everybody to witness the trial of Aristotle's saying about falling bodies.

So one morning, around the famous leaning Tower of Pisa, there was a great stir of people. Professor mingled with student, cleric with layman, on that day. All had gathered to witness the contest which would decide the downfall of either Aristotle's principle or Galileo's teaching. Which was it to be? Aristotle, the renowned sage, or Galileo Galilei, a mere youth of twenty-five? It seemed an unequal match.

"The youth is headstrong, as well as deluded," sneered one gownsman politely.

"He won't go far with such crazy notions," rejoined another, shrugging his shoulders. "As you will soon see," he added, pointing to the tower.

The students, however, who liked Galileo, were anxious. "Would to Heaven," you could hear them say, "that Maestro Galileo might succeed!"

Meanwhile the figure of Galileo, with stocky frame and reddish head, was showing itself on the top of the tower. In his left hand he balanced a ten-pound shot. In his right, a one-pound shot. The crowd below became tense. A shout went up as he suddenly let go of the shots. The two weights cut the air, and — to the greater glory of Galileo — both struck the earth at the same time, just as he had said they would.

A few die-hard Aristotelians refused to believe their own eyes. They even accused Galileo of using magic. Nevertheless, from this time onward, though he continued to be opposed more bitterly than ever, partly from ignorance, partly from envy, he leaped into fame at home and abroad. In fact, his popularity all over Europe was such that often his lectures could not be given indoors, so large were the crowds that wanted to hear him.

But what a disturbing fellow he was! Just when you thought you had learned something from the books of some ancient philosopher, along came Galileo, not at all

Galileo suddenly let go of the shots.

abashed by the reputation of your philosopher, and tried out the idea with his hands and eyes. Likely as not, he proved that you had learned nothing but a worthless lie.

One evening, for instance, Galileo was at the Duke's house among a group of scientists.

". . . ice, now," some one happened to remark, "is condensed water, and — "

"No, it isn't," said Galileo abruptly. "It's rarefied water. That's the reason ice is lighter than water."

"Ice lighter than water! What an idea! Read your Aristotle, my friend."

"Aristotle," replied Galileo calmly, "was a very great man, but he made many mistakes. If ice is heavier than water, why does it float?"

"That depends," retorted his opponent, "on the shape of the ice — as Aristotle says."

Galileo did not argue. There was a way to decide any

question — experiment. In a basin of water he put some ice. "Choose your shape," he invited. The result was undeniable. No matter what the shape, the piece of ice floated. It was lighter than water. That was Galileo's way. In scientific matters he cared not a rap for authority.

A powerful lord of Italy, one of the Medici family, invented a dredging machine. He sent a model of it to Galileo for his opinion. Now Galileo was living in poverty, and here was his chance to win favor. Here it was indeed, but the young scientist rejected it because it meant that he would have to stoop to flattery and lies.

"Your machine is worthless," he said bluntly.

The nobleman was furious, and built his machine defiantly. That did him no good, however. The machine would not work.

In the meantime, Galileo carried on his own mechanical inventions. At this time the most noted among these was the sector, which is used even yet by draughtsmen. In all Europe demand for his instruments sprang up, and to such an extent that Galileo opened a workshop for their manufacture.

III

One summer day, the news reached him that an optician in Holland had made a startling discovery. The optician had, by accident, held two lenses: one he held at arm's length, the other close to his eye. Peering through both at once, he was amazed to find that objects appeared upside down, and larger than usual. The reason for this peculiar fact he did not know, nor could anybody tell him.

So much Galileo heard. The wonder of it! Under your very eyes an object grew larger! Distant things came nearer! What secret of Nature was hidden there?

Galileo spent the night thinking. "Two pieces of glass,"

he reasoned. "Should they be flat, convex, or concave? Not flat, because that does not bend the rays of light that pass through it. Well, then: two concave lenses, two convex, or one of each — which should it be? Let's see . . ."

On the following day, he had not only discovered the reason why a spyglass brings an object nearer, but also had made one which far surpassed in power the original glass of the Dutchman. Galileo's glass, moreover, showed the object upright.

But he was not satisfied. He worked for perfection. Within six months he had created a telescope which magnified an object a thousand times, making it appear more than thirty times nearer. With this powerful instrument, he gazed overhead into the skies, and things undreamed of began to glimmer and whirl and wink down on him.

He turned his glass on the moon. The ancients had stated that the moon was polished and smooth. Yet there, before Galileo's eyes, was the surface of the moon, rough with deep shadows and high lights. What do these shadows mean? "Mountains on the moon," concluded Galileo. "The moon is a body similar to the earth; only, as Copernicus says, it turns around the earth."

The world began to take an interest. The stargazer turned to the sun. He looked and was puzzled. The glorious lamp of heaven was spotted and blotched. And day after day, as he stared at them, the spots seemed to move and disappear around the rim of the sun. Then some of them reappeared on the opposite side. What did *that* mean?

"The sun spins around like a top," announced Galileo.

But the glory of the heavens first burst forth when Galileo trained his spyglass on that cloudy expanse known as the Milky Way. Everybody who looked up at the heavens at night had marveled at the blueish-white stretch, like a ribbon across the sky.

"What is it?" they asked.

"Millions of stars, too far away to be seen by the eye alone," was Galileo's answer.

The world was breathless with excitement. Galileo was discovering the hidden universe! But the most amazing spectacle came on the night of January 7, 1610. The discoverer, that night, turned his attention to the planet Jupiter. He was a little surprised to see three bright stars near the planet, two stars on one side, and one on the other side. It was nothing unusual that he should discover a few more stars. But the next night he found that these three stars were in different positions. All were on the same side of Jupiter! Galileo was astounded. And what was his excitement when one of the stars disappeared around the edge of Jupiter! A few nights later he saw four stars where before there had been three.

Galileo was no longer in any doubt and made the announcement: "There are four moons wheeling around Jupiter. Jupiter has four satellites." His glass was not strong enough to see the other five moons which have since been discovered.

The world could contain itself no longer. Every one wanted a telescope with which to see these marvels. The Queen of France, when hers came, shocked the court by falling on her knees with excitement, so great was her impatience to see Jupiter's moons, and the mountains on our earthly moon, and all the new worlds of Galileo. King Henry of France sent an order to Galileo for a star to be named after him. It was a matter of business with the king. He would pay for a star, as one pays for a rose. Let the star, preferably a nice big one, be named "Henry." Alas, the king had to do without his star.

To the mass of people, Galileo had simply opened the heavens and shown millions of new stars, spots on the sun,

mountains on the moon, and such-like wonders. But for scientists he had done a far more significant thing — he had proved beyond any doubt that Copernicus was right. He had answered the sneer of the enemies of Copernicus, "Show us!"

"Those planets whirling around Jupiter furnish a model of our solar system," said Galileo, and it could not be denied.

But despite the world-wide chant in praise of Galileo, the hero's way was by no means rosy. His old antagonists, the Aristotelians, had the usual weapon of refusing to admit what they saw with their eyes. "This is some trick of Galileo's," they said. "These new planets cannot exist. Why, Aristotle does not mention them." Many refused even to put their eye to the telescope. "I will never admit the existence of those moons of Jupiter," each said.

In addition to such prejudice and envy, Galileo began to suffer from bodily illness, which affected his eyes. To complicate his hard lot still more, family difficulties arose to plague him. But against all these evils, and many more, he kept a stout heart. He had one great cure for every ill: work.

"Work, and you forget your troubles," he was fond of saying over and over again.

In a letter of July 4, 1637, to a friend, Galileo writes, " . . . the sight of my right eye, that eye whose labors have had such glorious results, is lost forever . . ."

Six months passed and he was totally blind. Then it was that the great English poet, John Milton, visited him, little realizing that he, too, was destined to end his life in a blind night. But as long as there was a spark of life in the infirm old hero, he set it aglow with all his soul. Crippled and sightless, he still carried on his scientific work . . .

The last glimpse we get of Galileo is impressive. He is

feverishly trying to complete an invention before death overtakes him. At the time of his death, which occurred on January 8, 1642, he was heroically imparting to his son plans for this invention, a pendulum clock based on his youthful observation of the lamp in the cathedral of Pisa.

CHRISTIAN HUYGENS

(1629–1695)

Inventor, Dreamer, Mathematician

I

In the country of Judea, one day, about two thousand years ago, two servants met and spoke together thus:

First Servant: Is it really true what they say about you?

Second Servant: Certainly. At the king's court, I was a timepiece, and was treated pretty well. At night and meal times, I was relieved by my brother, who was also a timepiece, just as my father was in his day. Indeed, I come of a family of timepieces.

First Servant: How's that? Have you no sand for hourglasses in your country, that you must tell time by men?

Second Servant: What! We, no sand! Enough . . . But the king is more precise about the time of day than other people. No hourglass for him! The human pulse, when it is healthy, is much more accurate than your trickling sand. As for sundials — what good are they when the sun doesn't choose to shine?

In this way does a German author describe the ancient attempts to measure time.

There was one other and more successful way than any of these, however: the water timer. That the regular trickle and flow of water marks the passing hours, is an old human experience. Time flows as well as flies.

> "Men may come and men may go
> But I go on forever,"

is the song of the brook.

"You lose water," is a Roman rebuke to an idler. Even to-day we sometimes hear it said, "Much water has flowed under the bridge since I last saw you."

It was quite natural, therefore, to place a basin filled with water in such a way that it would empty itself from sunrise to sunrise. It would have been awkward to try to carry a basin of water for a timepiece in your vest pocket, of course, and you could not have been sure of keeping a precise engagement for lunch by it. But then no one expected you to do that. It was enough that you could vaguely know the passing of your day. When the basin was half empty, you supposed that the day was half gone.

Later, it occurred to some one to put an iron float in the water, and on the basin a face with twenty-four circles, one for each hour. A dial on the face was connected with the float, which as it sank with the falling water, moved the dial across the circles. And as it came to each circle or hour, the dial released a metal ball which dropped on a pan, sounding a note like a bell.

"A clock!" people called this time machine, for the word *clock* means "bell."

The water clock was a great advance over the sand-glass. It counted each hour of the day. But still you could not have depended much on it if you had had to make the twelve fifty-four train. Fortunately, in those days there were no trains. So, to the workman, in a world which moved slowly, without railroads and modern industry, the exact time of the day was of little importance. To the king, it was of some importance. But if you happened to be an astronomer in the days following Copernicus, this lack of an accurate measure of minutes and seconds crippled your work, for, in observing the stars, even a few seconds are of tremendous importance.

Galileo felt the handicap and in the last years of his

life began work on a new kind of clock that would tell not only the hours, but the minutes and the seconds. It would run not by water or sand, but by the swing of a pendulum.

The prospect of a clock so exact filled scientists with delight. What a boon it would be! They were sure to have it, too, for what the great Galileo undertook, he did not fail to accomplish. Suddenly, with the death of Galileo, the prize seemed to be snatched right away from the outstretched hands of the world.

Who could finish what Galileo had begun? Where was the genius to fill the great gap, from what country would he come, from what family? The stage was empty and all eyes fixed upon it when out stepped the Dutchman, Christian Huygens.

Christian's father, Constantine, was one of Holland's most illustrious noblemen and brilliant poets. At his wish, his son took up the study of law. But the young man was too keenly interested in every other branch of study not to stray from his law books. He strayed so often, in fact, that father Huygens ruefully decided it would be best if his eager and pleasant son abandoned law for something more to his liking.

But what? Like Galileo, Christian was an accomplished musician; he was an able biologist — the study of living things fascinated him. But — there again, like Galileo — the subject to which he turned most gladly was mathematics, the language of science, and heart and soul he gave himself up to it.

In a short while, the youth's discoveries attracted the attention of the philosophers. To be sure, the world of people on the street did not yet hear of him. His thoughts were not yet their thoughts.

"The larger the diameter of a circle, the larger the cir-

cumference; what is the relation between these two? . . . Look at the end of that spoke in the wagon wheel turning down the road! What kind of curve is it writing in the air? . . . How did the whirling earth come to have flat poles? . . ."

All these questions Christian Huygens answered in a book which he wrote. To the philosophers these were startling discoveries. The young author was hailed as a great man.

In the footsteps of Galileo, Huygens' path led him to a study of the heavens. Here the old bother of having no exact clock plagued him. He was stuck just where Galileo had been.

"There is no use going on," he thought, "until I settle the problem of the clock."

He adopted his master's idea of the pendulum. "The shorter the pendulum," he knew, "the faster it will swing back and forth. Also, the whole business depends on what sort of curve the pendulum swings in."

With these two beliefs he went to work. Years passed. The world had almost forgotten its dream of having an accurate clock when in June, 1657, Christian Huygens came forward with the first pendulum clock. No more hopeless guesses about seconds of time! Let the world move as fast as it would, it had the sanction of Christian Huygens' pendulum clock.

There was one trouble: the pendulum was not a good sailor. On the lurching deck on a ship, it was of no more use than a water clock. Christian Huygens was no Indian giver, to give on land and take back on sea. To invent a seafaring clock meant more hard work for the young scientist, but in the end, he devised the great scheme of replacing the pendulum with a coiled spring. And that is the idea of our modern watch.

II

Now that he had a good clock, Huygens was ready to time the stars in their movement across the heavens. But here the way was barred: Galileo's telescope was too weak to show any new sights. And there was no use trying to make the telescope larger, for beyond a certain size, the lenses blurred the image as opera glasses do when they are not well focussed. It was a serious matter. It meant that never, perhaps, would the far-lying stars be seen.

The genius of Galileo lived ardently in the mind of Huygens. He who made Galileo's dream of a pendulum clock a reality carried on the work to the telescope.

"Something is wrong with our way of grinding and polishing lenses," he decided.

In quick time he devised a new way. So amazing was its success that from a spyglass a few feet long, the new instrument became a telescope 210 feet long! To-day, of course, the telescope has grown from a magnifier which an individual can manipulate and put to his eye, to a stupendous machine, housed in a vaulted tower, and moved by electric power; a man clambering on the largest one is as an insect on the leg of a table. But in Huygens' day, his telescope was nothing short of a miracle.

Scientific men, moreover, will always be grateful to Huygens for a very clever device. He marked off his telescope lense like a ruler. The result is, that when you look through a telescope, the rulings appear to be on the surface of the body seen. By this means, you can judge the distances on the stars as though you were actually measuring them by a ruler.

The cloak of Galileo upon him, Huygens turned the clear eye of his telescope on the sky. He searched out the planet Saturn and there fixed his gaze. He remembered what a mystery Saturn had been to Galileo; how, one

night, Galileo fancied he saw a moon on either side of Saturn. The Italian seer had been about to announce this confidently when to his astonishment the moons changed into long arms that stretched straight out from the edge of the planet. The mystery deepened when he found the arms curved like handles. His bewilderment could have been no dizzier had he seen two stars collide.

"The weakness of my intellect," Galileo wrote in chagrin, "the terror of being mistaken, have greatly confounded me."

Galileo had died and a generation of men had gone by, but the mystery of Saturn remained unsolved, unsolved until Christian Huygens, armed with his new telescope, attacked it. His faith in his new glass was at stake; his power as a scientist was at stake. Huygens peered through the glass; he made out the splendid giant Saturn . . . An awesome, terrifying spectacle, for Saturn is not a simple planet at all. It is a brilliant ball, girdled with a huge ring, and nine moons riding round it! A vision to make Christian Huygens rub his eyes. There is nothing else like it in the sky. It looks like a heavenly machine, or a magnificent toy of the gods.

"Saturn is girt with a ring," announced the discoverer simply, "and I have seen what was never before seen, its brightest moon." We call that moon Titan.

The mystery of Saturn at last solved, the glass of Huygens swept again over the face of the heavens. Now there are in the sky strange forms, most of them invisible to the naked eye. They look like patches of cloud, like mists in the sky, but they are the raw material which becomes stars and worlds. Nebulae, scientists call these distant worlds.

Some are round like spirals, others long and narrow. Some have the shape of dumb-bells, others of rings. So far away are most of them, that the light they shed has trav-

eled a million years to reach us. The sky is strewn with these worlds; in fact, there exist hundreds of thousands of them, and the astronomer's task is to find and study them.

One winter's night, Huygens pointed his telescope into the southern skies, to a very bright group of stars known as the constellation Orion. The brightness of Orion was always a cause of marvel. Homer, for instance, speaking of the splendor of his hero Achilles, says that he shone "like the star which rises in autumn and sends its rays among many stars in the depth of the night, and is called the dog of Orion."

Huygens knew the stars of Orion well enough. So did everybody. But what no one had ever before noticed, and what Huygens now discovered in the constellation, was a wreath as of smoke.

"A nebula in Orion!"

III

Christian Huygens had at last become a great world figure. The Royal Society of England invited him to lecture to its members. Princes began to extend their favors to him. The King of France, in fact, lavished so much attention on him that the great scientist was induced for a while to settle in France.

For hard work as well as genius, his name was a byword. He excelled in everything, it seemed. Somehow he found time to become even a remarkable musician. There was also in his amiable, kind disposition a touch of the dreamer.

"To live on another planet," he often imagined, "would be a strange experience. Perhaps there *are* living beings on the other planets, millions of miles away from us. Why not? On Mars and Jupiter I can see shadows, which must be water or clouds. And if there is water, why not plants

and animals, and perhaps even Man?" He did not *know*. He was just spinning out a reasonable thread of fancy. "What moonlight nights on Saturn, with nine moons playing down their beams! Yet if you lived somewhere on the equator of Saturn just now, you would be in total darkness, for there I see the gigantic shadow of the ring."

His musings then turned to another planet: "How hot it is on Mercury! Three times nearer the sun than we are, Mercury is nine times hotter. But then, an inhabitant of Mercury, looking at the little dot in the sky known as Earth, must pity us for our cold and dreary light. So our light is in comparison to theirs! If we could pay Mercury a visit, our return to Earth would be like coming into a dim room from the bright sunshine."

On he dreamed for the space of a book, "The Celestial Worlds Discovered" — but not for longer. Soon he was

He was grappling with one of the hardest questions — what is light?

grappling with one of the hardest questions of all time — what is light? Every one has been out on a bright day and felt the pleasant heat of the sun. He has perhaps watched the world light up at dawn.

"But what causes the pleasant heat and the dawn?" scientists were asking. "What are sunbeams?"

Now Christian Huygens had often thrown stones into a lake and watched the ripples of water. He had seen the gentle waves form and travel until they reached shore. This, he believed, is the way light acts. Only at what a speed! Light waves travel as much as 186,000 miles every second.

By means of his famous "wave theory of light", Huygens worked out an entirely new branch of learning: the science of optics; and it is for this great work that modern scholars still study him.

But perhaps the greatest of all Christian Huygens' achievements, even greater than his perfection of the clock and telescope, was his paving of the way for our next hero, Isaac Newton. And not only for Newton. When Huygens died on the eighth of June, 1695, at the Hague, he left the knowledge which all later heroes were to use in carrying forward the work of civilization.

SIR ISAAC NEWTON

(1642–1727)

"The Greatest Genius That Ever Lived"

I

WHEN the father of modern science, Galileo, died, he left a large legacy of unfinished work to the sons of science. Christian Huygens undertook to perfect the pendulum clock and the telescope. There were, however, even more important questions.

The new stars, which Galileo had shown to king and peasant alike, were so dazzling that men did not notice that Galileo was doing something strange. Only when people grew accustomed to the existence of so many new stars, did they see the great master rolling balls along a board! He would tip the board a little, then roll the ball down. This he repeated over and over, each time inclining the board a bit more, until it was vertical. And each time he estimated how long it took for the ball to reach ground. Faster and faster it went, he noticed, the farther it traveled. Precisely sixteen feet faster one second than the previous second. Again, Galileo would put two boards together in the shape of a V, start the ball down one side, and observe how high it rolled up on the other side.

Queer doings these, but Galileo had an uncanny feeling that the mystery of the heavens could be solved by such humble experiments.

"A ball rolls along a path; a planet goes around the sun," thought Galileo. "Why? How? That question we must

settle: *how* things move." That was Galileo's greatest moment of genius. No one before had ever dreamed that there was a science of motion — dynamics, as it is called.

"Motion!" people exclaimed. "What is difficult about that? A thing moves because — well, because something else pushes it. Some force, you see, makes it move. It is so with the planets. Some force is continually shoving them around and around."

When Galileo finished his ball playing, he retorted, "Once a thing is moving, you don't need a force to keep it in motion. It will go on by itself forever. On the contrary, you need a force to stop it."

"How can that be?" objected his bewildered students. "Even the brass ball you rolled along the board gradually came to a stop."

"That," replied Galileo, "was because there was a force stopping the ball — the friction of the board against it. But when there is no friction, as in the sky, the moving body moves forever straight on."

His life over, the spirit of Galileo's genius seemed to follow his law of motion and move straight on, for in the year in which he died, Isaac Newton was born in Woolsthorpe, England.

During the next twenty-three years scientists tried to make Galileo's laws of motion explain the movements of the planets. "We can now understand," they agreed, "why a moving planet keeps moving. But why does it go in a circle around the sun, and not in a straight line?"

At Cambridge University the young scholar, Isaac Newton, thought about it, too. "Our ignorance continues," he said to himself, "because we haven't the proper mathematical method." That conclusion spurred him on to invent calculus, a method of computation now studied by college students of mathematics. Coming from young Newton, this work of genius was all the more astounding for,

when he had entered the University four years previous, he was said by his professors to be a poor student in mathematics.

But then, Isaac had always been a surprising lad. He was forever inventing one thing or another. At Woolsthorpe the simple villagers still talked of that fearful sight in the sky one night — a comet with a glowing tail, riding over their heads . . . Finally the comet caught fire and revealed itself as one of Master Isaac's kites with a paper lantern tied to its tail. Another time he made a windless windmill. Since Isaac was scientifically minded, he despised mills which depended on a fickle wind. So he built a toy mill of another kind. Inside his mill he put a mouse on a treadwheel. He called this mouse the miller, since it moved the mill and ate up the flour.

When he was doing his spelling lesson, questions not in the book would pop into his mind and interfere with his learning. "How fast is the wind blowing?" the lad once wondered. "How can I measure the speed of the wind?"

At the cost of his spelling lesson, he found a way at last to test the wind. With his back to the breeze, he jumped as far forward as he could. He marked the spot "with the wind." Then he faced the breeze, and again jumped "against the wind." After subtracting, the little scientist could speak gravely of a "stiff five-footer" or a "roaring eight-foot gale."

His lessons, of course, suffered so from such preoccupation that Isaac hovered somewhat nearer the tail than the head of his class. One day, the stimulus to become a good scholar came to him in the shape of a kick in the stomach. The foot that kicked him belonged to a bright bully who was ahead of Isaac in the class. In retaliation, Isaac first beat his antagonist with his fist. Then he began to beat him with his brain, and the speed that Isaac gathered in his studies, the acceleration as Galileo might have called it,

carried him to the very head of his class and perhaps beyond his teacher.

Mrs. Newton, who owned a farm, hoped that her son would become a farmer. Isaac was therefore taken out of the grammar school and started on his career of tending the cattle, weeding the vegetable patch, and taking his truck to sell at market. But the meadow was a pleasant place in which to model in wood with his knife, the vegetable patch was near a hedge where one could sit in the shade and solve problems in mathematics, and the market place was near his friend the apothecary who had interesting books. The result was that the weeds grew rank in the patch, the cattle ate the corn, and the customers bought elsewhere. In despair, Mrs. Newton sent the poor farmer back to school where he could be more successful. He was successful, and in time went to Cambridge University where the works of Galileo and Huygens absorbed him.

II

"Why do planets move in a circle around the sun?" That question made Newton forget that he had not eaten dinner, or that he was going forth without a shirt. And the objection, offered to Copernicus, that a whirling earth would fly to pieces, Newton feared, had not been answered any more than the question, "Why does an apple fall down and not up?"

"Gravitation!" some called the force.

This was a vague answer, thought Newton. One might just as well say, "Abracadabra", if all he could answer was, "Gravity." He must show exactly — with figures — how gravity works.

"Well, how does it work?" he questioned. "The moon goes round the earth, the apple falls to the earth . . . The earth must be forcing both the apple and the moon.

But the moon does not fall down. Maybe that is because the moon is so much farther away than the apple . . . Ah, here's the story! The moon is trying to get past the earth, but the earth pulls upon it and, as it turns, pulls the moon round and round with it. In fact, the earth would pull the moon right down to it with a crash, as it does the apple, were not the moon, fortunately for us, too far away. The pulling force of the earth becomes weaker and weaker as the body it pulls is farther and farther away. Now how much weaker? The young scientist drew a few circles and made a few calculations. "I see it! If the moon is four times as far away as the apple, then four times four — you square the distance, which is sixteen, and use the inverse of it, one sixteenth — the earth exerts only one sixteenth of the force. The inverse square! That sounds plausible. But wait! Does not the moon or the apple have any say in the matter? Does not each return the pull? It must! Every body, even if it is a speck, draws every other body. The apple and the earth pull each other, but of course the apple is so small, it has little force. The moon and earth pull each other together. If they did not, the moon would fly away out into space. But no! The earth pulls it. That is why the moon must keep whirling around it."

"That is how gravity works," thought Newton. "Now for the test: the earth, the books say, is about 21,000 miles in circumference. Then the distance of the moon from the earth is . . . At that rate, according to my reckoning, it should take the moon about thirty-two days to go once around the earth," Newton figured. "But, alas! It does not. It takes the moon about twenty-seven days . . ."

Newton felt the bitterness of defeat. All his eagerness to discover how gravitation works seemed like an empty dream, and he laid away his papers. The sense of his failure lay upon him for sixteen years, until one day some

one mentioned to him that a French scientist had discovered a mistake in the measurement of the earth.

"It is really 25,000 miles around," Newton was told.

Home he rushed. Maybe he had been right after all. He must make his test again by the new measurement of the earth. He was so excited that he could not divide one number by another — he, the greatest mathematician in the world! A friend had to do the arithmetic for him, and when the answer came, it showed that Newton's theory had been right, that Newton had discovered the true law of gravitation sixteen years before.

Now was the time for Newton to shout, "I have discovered the reason why the earth turns round the sun, and why it does not fly apart as it turns." But so modest was he that he said nothing about it.

A few years went by. Then one day Newton had a visitor from London. It was Halley, the astronomer.

"We cannot solve this problem," said Halley; "we need your help. Imagine that gravity works by the law of inverse squares. What is the path of a planet in going round the sun?"

"An ellipse," promptly answered Newton.

Halley was taken aback by Newton's readiness. "Why, how do you know?" he gasped.

"I've calculated it."

"Show me your papers."

Newton went to his desk, but was unable to find the papers. So careless was he and so modest that he had thrown them away. But he re-worked the figures for Halley and in addition showed him all that he had written on science. Halley was lost in admiration.

"These are the greatest discoveries ever made," said he. "I shall have the Royal Society publish them."

The Royal Society, however, had spent its last farthing on printing a book on fish, so that Halley had to publish

Newton's "Philosophiae Naturalis Principia Mathematica", or "Principia" as it is usually called, at his own expense.

Newton's laws have been our finest tool in solving the problems of nature. So many puzzles were made plain by them that scientists felt they had few more to learn . . . such puzzles as why there are tides, and how much matter there is in the stars.

About one hundred years ago, the planet Uranus was seen to behave in a startling manner. Here was a majestic planet, with a journey of over five billion miles to travel regularly around the sun, reeling erratically, as though it cared nothing for the law of gravitation laid down by a puny mortal.

"Is Uranus an outlaw, or is Newton's law false?" wondered some astronomers.

"There must be some hidden planet pulling on Uranus," thought others; "otherwise Newton's law fails."

"But where shall we look for the new planet? Is it likely that there is a planet which we with our great telescopes know nothing about?" asked the skeptics.

Newton's law showed that there must be some giant planet pulling Uranus out of its normal course. It showed, moreover, where that planet ought to be.

What excitement there was when the astronomers turned their eager telescopes to the spot! And what a triumph for Newton, for lo, a giant planet — Neptune, they called it — rolling along 2800 million miles from the sun, never before seen by a human eye, was now ferreted out by Newton's law of gravitation!

III

Isaac Newton was a mild, pleasant person. Most of his life he was very poor because he gave away his money to

whoever needed it more than he. He found plenty of relatives who needed his money. This open-handed charity embarrassed him, for there was a time when he could not afford to pay his dues of one shilling to the Royal Society. The Society, of course, excused him.

He may have been careless and absent-minded, but never, it seems, about other people; only about himself. He worked so steadily that he scarcely remembered to eat, and begrudged himself his four or five hours of sleep. But if he did not work for money, he certainly did not work for glory. His modesty, in fact, was exasperating to the scientists of the Royal Society who waited eagerly for a word from him. They knew that he would not publish his discoveries; he was too busy to say anything about them.

"Dear Mr. Newton," the Society would write. "Have you any findings to tell us about?" As likely as not, he would forget to answer the letter.

Once Newton invited a friend to dinner. The guest arrived; dinner was served. Newton was in his room working. The friend waited some time and then, partly from sheer annoyance, partly from a desire to be smart, ate all the dinner, Newton's share included. Presently the host entered, greeted his friend, and sat down at the table. He lifted the cover of the chief dish, stared awhile blankly at the bones, and at length said with a sigh: "I forgot that we have already dined."

His absent-mindedness, however, did not extend beyond his personal life. In all other things no one was keener or more conscientious. For instance, the English government thought that its best scientist should have more time and more money. It therefore appointed him Master of the Mint, in order that he might be free from teaching and have more time for himself. Newton, however, took his duties more seriously than the government intended.

From early morning until late in the evening he was at the mint. The result was that he neglected his scientific work, but the mint became more efficient than it had ever been before.

At this time it was the entertaining custom for mathematicians to challenge each other to mathematical duels. In these Newton was never beaten.

In June, 1696, Johann Bernoulli, a famous mathematician, announced two problems and challenged all Europe to solve them within six months. The six months passed, and no one had yet solved the problems. But the author received a letter from Leibnitz, one of the greatest mathematicians and philosophers of all ages, asking that the time be extended to the following Christmas, as the problems were unusually difficult and the time too short. The challenger agreed.

On the evening of the twenty-ninth of January, 1697, Newton came home from a hard day at the mint and found waiting for him a copy of the magazine containing the problems. At once he began work on them, eight months after everybody else. The following morning he gave the solutions to the President of the Royal Society.

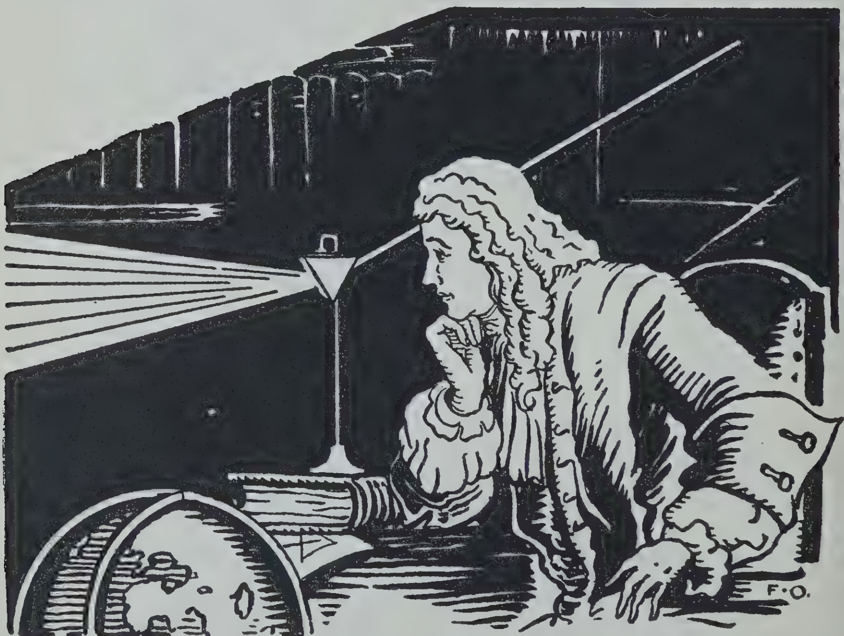
IV

When Newton peered through one of Galileo's telescopes, he, like Huygens, thought about the blur in vision. Poor Galileo had probably lost his sight by straining through the murky glass. "The trouble," Newton believed, "would be overcome if we knew more about light."

He had noticed the beautiful iridescent shades that play in a bubble of soap, or in the glass prisms of the chandelier, and he must have gazed long at a rainbow. He had a suspicion that ordinary white light was not a simple affair after all, and he began to experiment.

He made his room totally dark except for a tiny hole in the window shutter. Through that hole one beam of sunlight streamed into the darkened room and fell upon the opposite wall. Then, right in the way of the sunbeam, Newton put a glass prism so that the light went through it. A wonderful thing happened! There on the wall, instead of the round spot of white light, Newton saw a band of seven colors: red, orange, yellow, green, blue, indigo, and violet — the colors of the spectrum, as we now call it.

The secret of light was now as clear to Newton as light itself. "Sunlight is a combination of the seven colors of the spectrum," he said.



The secret of light was now as clear to Newton as light itself.

There is large meaning in this. When we say, for instance, that grass is green, the truth really is that the grass gives back the green light of the sun's rays. Six colors it absorbs, only the green it reflects.

"The trouble with Galileo's telescope," Newton realized, "is that the lenses act like prisms; they break up the light and blur the view. That must be corrected."

In the end he invented a new kind of telescope — one form of the reflecting telescope. Today the largest telescopes in the world are built so that they may be arranged in this way or in some other.

The world has never been able to restrain its admiration for Isaac Newton.

"The greatest genius that ever lived", a famous scientist called him.

"If all the geniuses of the universe were assembled," said the French writer, Voltaire, "Newton should lead the band."

And Alexander Pope, the leading English poet of Newton's day, wrote:

> "Nature and Nature's laws lay hid in night;
> God said, 'Let Newton be', and all was light."

But Newton himself was modest to the last. "I have been but as a child playing on the seashore," he said, "now finding some prettier pebble or more beautiful shell than my companions, while the unbounded ocean of truth lay undiscovered before me."

ANTOINE LAURENT LAVOISIER

(1743–1794)

The Founder of Modern Chemistry

I

WHEN the American colonists were growing indignant over King George's tyranny and the citizens of France were clenching bony fists at their fat king, Louis XVI, there took place daily in the King's Gardens of Paris a curious event, somewhat as follows.

Before a small but elegant group of ladies and gentlemen, the social best of Paris, Professor Bourdelin stands nervously. In a low monotonous voice he is explaining an idea in science. His distinguished audience, however, seems to be giving him scant attention. The lace bosoms of the men rustle, their silver shoe buckles clink, and the powdered curls of the ladies toss impatiently.

There is at least one in the audience who is listening eagerly. He is seated as near as possible to the professor and, notebook in hand, seems to be treasuring every precious word. It is Antoine Laurent Lavoisier, the young law student, who has slipped away from his law books to enjoy the excitement of a lecture in science at the Royal Gardens. The handsome youth must be known to most of the fashionable group, for he comes of a rich family; so rich, in fact, that his house has glass windows. But they say of young Lavoisier that he is not purse-proud. The only use he seems to have for money is for the purchase of

books, and a good student he is. Did he not at college win a prize in literary composition? It is rumored even that he is writing a play, but some say that his deep interest is really in music and painting. Everybody agrees, however, that he has a winning, sympathetic nature.

"Everything that burns," Professor Bourdelin drones on, "does so because it has particles of fire in it. When wood burns, for instance, its fire particles rush out and leave an ash. That proves that wood is made of fire particles plus ashes. Stone has no fire particles. Therefore it cannot burn."

Here and there a yawn is stifled. Presently the professor concludes his lecture and retires, much to the relief of his audience.

"How tiresome! Who cares about fire particles!" There are polite shrugs. "Ah, here is Master Rouelle . . . Master Rouelle is here at last."

Applause ripples through the audience, and a stillness falls. Every eye is on the platform, where now stands a striking figure in velvet breeches and cape, with carefully powdered wig, and small tri-cornered hat under his left arm.

"You have all heard from my esteemed colleague," begins Rouelle in a calm, deep voice, "about fire particles that rush out of burning bodies." He pauses, and puts down his hat. "We shall see."

From the table he picks up a lump of sulphur. Pensively he looks at the yellow clay in his hand. "We shall see," he repeats slowly.

Suddenly he thrusts the lump into a scale. "A pound," he snaps out. "Mark you, this sulphur weighs a pound."

With quick gesture he reaches for a bowl. Into this he puts the pound of sulphur to which he applies a lighted taper. A bluish flame rises up slowly and pungent fumes that sting the nostrils fill the chamber. Through the in-

tense smoke over the burning bowl the audience sees the face of Master Rouelle.

"A pound," he roars, "ladies and gentlemen! And when the fire particles" — he pronounces the words scornfully — "when the fire particles rush out, it should weigh less than a pound, should it not? Well, let us see."

The audience watches, fascinated. The flare dies out. Master Rouelle now turns to the scales, one side of which is being held down by a one-pound weight. Into the other he slides the contents of the bowl — the ashes — which should weigh less than a pound. The scales tip . . . They balance . . . They tip, and there is no doubt that the ashes weigh *more* than a pound.

Master Rouelle thumps the table with his fist. "Does not this simple experiment show you that there are no such things as fire particles lurking in things?" he cries triumphantly.

The demonstration is over. The audience applauds the discomfiture of Professor Bourdelin and the triumph of Master Rouelle. As he leaves the King's Gardens, young Lavoisier thinks with dismay of the law books waiting for him. He cannot go back to them, he decides. Master Rouelle has carried him too far away . . . The adventures and dangers of the scientist beckon to Lavoisier.

II

Several years went by, years of close study for Lavoisier. His brilliance as a scientist was gaining him fame. Already he had been given a prize for an essay on the best way to light Paris at night. The question, why things burn, was interesting him.

He worked hard. The day was not long enough for him, and he begrudged the time he spent eating. So he put himself on a milk diet. At this, his friends and family protested.

"Dear Mathematician," they said, "an additional year on earth, even if you accomplish less, will be of more value to you than the gratitude of mankind for your sacrifice."

Lavoisier did not agree. His zeal for the public welfare was too great. At this time Paris was suffering for lack of suitable drinking water. The young scientist was ready with a plan to pump in the excellent waters of the river Yvette. He also suggested a scheme for setting in hydrants against a fire. Unfortunately there was no money to carry out these measures. But the reward for his brilliant plans came to Lavoisier: the honor of membership in the Academy of Science was conferred on him when he was half as old as his fellow members.

Lavoisier was not satisfied with the method of experimenting in those days. It was not precise enough, he felt. There were not enough instruments and apparatus for weighing and measuring.

"How can we know what happens to things when they burn," he thought, "if we have no means of careful measuring? We must burn many substances in many ways . . . I must have machinery. This hit-and-miss guessing leads nowhere."

To carry out his plans he needed a great deal of money; and the only way he could get money was by going into business. He decided, therefore, to join an organization known as the General Farmers. This concern had nothing whatever to do with agriculture. It consisted of a group of men who bought from the king the privilege of levying and collecting taxes. The people of France hated the General Farmers, who were in many cases dishonest politicians out to rob them. As a result Lavoisier was looked upon with suspicion. It was expected that he would let the extortion of money from the poor go on, and take his share of the loot.

But Lavoisier was the soul of honesty. Like Newton at the mint, he took his business seriously. Often he tried to

reduce the taxes of the poor, rather than raise them for his own benefit. Though his scientific work was the dearest thing in the world to him, he was never too busy to seek remedies for bettering the lot of the poor. He was deeply pained, for instance, when he visited the hospitals and prisons and observed the squalid conditions there. From that time on, he continually used his influence to secure decent treatment for the inmates.

"If it is possible to make exception in the case of taxes," he said warmly, "it can only be in favor of the poor." And in 1788, when he had amassed a fortune, and the people of Blois and its vicinity were suffering from a severe famine, he donated £50,000 for their relief, of which they took only £38,000. This sum, they later offered to return, but he refused to accept it.

He established in 1778 a model farm in Blois at his own expense, in order to prove that if farmers only applied scientific methods to their lands, the country would become more prosperous. The venture turned out so successful and the suffering around Blois was alleviated to such an extent that to this day in that community they speak of Lavoisier as their benefactor.

The interest in this first model farm was widespread. George Washington watched it carefully from across the ocean. When Franklin visited France, he made a friend of Lavoisier. Indeed, the success of his experiment was so signal that it led to the establishment in 1785 of the King's Committee on Agriculture, and in 1788 to an assembly for the betterment of the poor. A member of this assembly writes, "It is Lavoisier who does everything. His name is heard every moment."

One more remarkable piece of public work the world owes to him. Through his efforts there were started in France a Bureau of Life Insurance and Old Age Pensions which gave the peasant an opportunity to invest small

When Franklin visited France, he made a friend of Lavoisier.

sums of money in such a way that he was assured a settled income in old age.

III

Lavoisier repeated the fire-particle experiment he had seen Rouelle do. But he was much more decisive about it. He burned a piece of tin in a closed vase. Before the burning began, he noted the weight of the tin, and the weight of the vase. When the burning or combustion was over, the ashes of the tin weighed more than had the tin itself.

"Where does this added weight come from?" pondered the chemist.

Chemists in those days never asked questions like that. If some one had propounded it, they probably would have said, "If tin weighs more after combustion than before — well, that's the nature of tin." But such an answer did not satisfy Lavoisier.

"The tin gets its added weight somewhere," he insisted. "You can't make something out of nothing. If my tin, vase, and air within the vase, weigh ten pounds altogether before the tin burns, they should weigh the same after." He found this to be true.

"Now," he went on, "if the vase weighs the same after the burning and the tin more, the air must weigh less. The air has given something to the tin."

He noticed that, after the burning, the air in the closed vase was unbreathable. "The pure air has joined with the tin." He was sure of it. "What is left of the air is another gas which we cannot breathe. Air must be a mixture of several gases."

He remembered that the English chemist Priestley had told him of a certain gas in the air which, when he had breathed it, made him feel very lively.

"There is a gas in the atmosphere," concluded Lavoisier, "which helps things to burn. In fact, without it there could be no burning, there could be no heat. Maybe we have heat in our bodies because we breathe that gas."

He continued his experiments with burning things. He noticed one more curious fact: that whenever he burned up sulphur, he always found an acid in his dish.

"The gas in the atmosphere — this pure air — has power to form an acid." So he called this gas by the Greek word meaning "acid-former" — oxygen.

When scientists learned that burning is just a fusing of the oxygen of the air with something else; that Lavoisier had proved that there was no such thing as fire particles hidden in wood, coal, or any thing else that burns, they were scandalized. "What! Who is this young fool Lavoisier?" they asked.

His friends begged him to re-consider: "You have upset all our ideas," they urged. "We no longer know where we are in chemistry."

"But in the mystery of science lies its beauty," thought Lavoisier, and he stuck to his guns.

The interesting discovery was now made by an English chemist, Cavendish, that there is a gas which burns. In his laboratory in Paris Lavoisier manufactured this inflammable gas, and on adding oxygen to it he found that water was formed. The "water-former", or hydrogen, he called this gas discovered by Cavendish.

"Water is no longer the simple liquid it has been supposed," announced Lavoisier. "It is a compound of two gases, hydrogen and oxygen." A glass of water, he further proved, weighs as much as the hydrogen in it, plus the oxygen.

This sort of experimenting brought about a revolution in the practice of chemistry. Lavoisier had made an exact science of it. He wrote a book on chemistry in which he showed future chemists how to work and with which he earned for himself the title, "The Founder of Modern Chemistry."

Now it occurred to Lavoisier that the human body must be a great chemical factory. "We inhale oxygen," he reasoned. "That starts heat in the body which keeps life going . . ."

Here the great chemist was interrupted.

IV

The French Revolution had struck. The starving people of Paris, marching to the Royal Palace, had forced the king to yield to their will. "Bread!" was their cry.

Lavoisier was enthusiastic. "A government," he believed, "is created to make all its people happy, not a small number only. It is a government for everybody."

"There are a few autocrats," he wrote to his friend, Benjamin Franklin, "who want to go back to the old sys-

tem of monarchy. But the best French thinkers are democratic."

In this crisis, France looked to its geniuses to help it. Lavoisier the people made head of the National Treasury. For this work he refused to take a salary. "I have enough for my wants," he said. "Just now, when France needs all its resources, I cannot consent to profit by her trouble."

The king, knowing Lavoisier's skill in financial matters, offered to make him his Minister of Finance. Since the nomination came from the king, he refused.

"I have sworn allegiance to the will of the people," said Lavoisier firmly.

Everything he turned to came out the better for his attention. As head of the National Treasury, he improved the system of coinage. He invented the decimal system of coins. It was found to be simple, and is in use today. But a much greater public work was his new system of weights and measures, the metric system. Almost all merchants in Europe and scientists all over the world use it now. Before Lavoisier's time, nearly every province in France had a different system of measurement, so that a merchant from Bordeaux, if he was buying in Lyons, scarcely knew whether he was getting a bargain or paying too much. The business world, as well as the scientific, owes Lavoisier a debt of gratitude.

The greatest public work of Lavoisier, however, was done when he was a member of the Committee on Education. First of all, he believed in free schools. "It is our duty," said he, "to provide education for children."

Then he outlined an entirely new course of study, the Industrial Arts Course. "Academic studies are not enough to offer to our children," he asserted. "We must also teach practical work."

He began his work of revising the entire school program of France, from the first grade up through the universities,

but suddenly the guillotine began to rumble in the streets of Paris.

The king and queen were among the first victims. It was considered a crime to have more than enough bread to eat in the house, and the heads of all who were not starving sat weakly on their shoulders. Fifty times a day the axe fell, to the tune of the "Marseillaise." Terror reigned.

All at once the cry arose, "The General Farmers! Those leeches who have sucked the blood of the Republic!"

Warrants were drawn up for the arrest of all the General Farmers. The charity, the public work, the genius of Lavoisier were forgotten. The same legal paper that had done for four thousand other wretches, served him, too.

It meant death. Lavoisier's friends urged him to flee. But the conscience of the scientist was clear and he did not wait for his arrest; he gave himself up.

Scientists the world over were horrified. They petitioned the stupid judge to save him from death.

Lavoisier took his fate calmly. "I have lived a useful life," he said, "and I am ready."

He requested simply that, since he was in the midst of an important experiment on the chemistry of perspiration, the judge spare him time enough to complete it.

"Only two more weeks of life," he begged. It seemed little enough for the brave man to ask, since the experiment was to benefit humanity.

"The Republic," was the amazing reply of the judge, "has no need of scholars."

On the eighth of May, 1794, this hero, who had made all the civilized world his debtor to the end of time, was led to the scaffold. Not a murmur disturbed his lips as he bowed his head on the guillotine. The axe fell.

"It required but a moment," wrote a fellow scientist, "to cut off a head, the like of which one hundred years will not produce."

JAMES WATT

(1736–1819)

"At the Head of All Inventors, in All Ages and Nations"

I

One winter day an English lord was being guided through the madhouse in Paris. As he gazed at the walls about him, his spare old frame shuddering at the human misery there contained, he suddenly heard a hoarse shrieking: "I am not mad! I am not mad! I have made a discovery . . . a discovery . . . "

"What has he discovered?" asked the nobleman anxiously.

"Oh," the guide answered, shrugging his shoulders, "something trifling enough. You would never guess it; he thinks he has found a use for the steam of boiling water . . . To listen to him, you would imagine that with steam you could navigate ships, move carriages, and perform other miracles. He has even written a book on the subject."

That was in 1641.

About one hundred years later in Glasgow, Scotland, one evening, a lad of thirteen and his aunt were seated at the tea table. They were silent for some time, until at last the aunt exclaimed impatiently, "James Watt, I never saw such an idle boy! For the last hour you have not spoken one word or done one thing but take the kettle off the fire and put it on again, holding now a cup and now a silver spoon over the steam, watching how the steam rises from the spout, and catching and collecting the steam

as it forms into drops of hot water. Are you not ashamed of spending your time in this way?"

To a man in Paris the fascination of steaming water brought madness; to a small Scotch boy, idleness. The madness destroyed the man; the idleness made the lad illustrious.

In his father's carpentry shop, they said of Jamie Watt that he had "a fortune at his fingers' ends", for he could wield tools more shrewdly than a skilled mechanic. Although he was too frail to sport with other boys, the knowledge that he gleaned from books, as he lay at home on the hearthstone, and the skill at his fingers' ends, enabled him to play in his own way. One evidence of this was a little electric machine which he built and with which he startled his friends with electric shocks.

His father's workshop was for him a realm of constant pleasure and surprise. Days were always delightful at the craftsman's bench. There Jamie had a small forge for his own use, and all he needed for his work was a supply of odd pieces of metal. A large silver coin, for instance, if it were shaped and drilled properly, made a fine ladle, and ladles were useful.

In his house there were several portraits on the walls. One was of an amusing man in a wig. "Who is that?" asked Jamie.

"Sir Isaac Newton, lad," answered his father, "one of our greatest men. Come, let me show you."

Leading Jamie into the workshop, he rummaged about until he brought forth a long tube with a glass at either end. "A telescope", he called it, and told Jamie that the stars and the sun and moon are bigger than they seem, bigger even than a large lantern . . .

In the still nights that followed, a small boy lay for hours on his back under the dark murmuring trees, with a tube stuck in his eye.

He would have lived happily enough despite illness, with his books on literature, botany, anatomy, and natural science, had not his mother, the mainstay of his early years, suddenly died. His home was broken up. His father, who had never been rich, now fell upon such hard times that he could not even support his son. Jamie, not yet fourteen and weak in body, went to Glasgow to make his way however he could.

And a meager enough way it was. He became apprentice to an instrument maker, and soon it was said that Watt's compasses and sectors were the best in the field. In his strong desire to learn everything about his trade, however, and keep up his studies at night in his garret, he overstrained and fell dangerously ill.

He recovered, only to find himself out of a job. His talent, though, was known. A professor of science in the University of Glasgow, having seen a sample of Watt's work, offered him a room in the University building, gave him some work to do, and urged him to make and sell instruments. Jamie Watt was happy. In his workshop the professors would gather, and as Jamie worked, they chatted about chemistry, mathematics, mechanics. They all liked the quiet youth who, in the midst of all their learned talk, kept modestly at his work. When they discovered with amazement that this same modest young man was their equal in learning and even their superior, their admiration and respect for him became immeasurable.

He was so studious, so thorough; his knowledge of science, which he got alone from books, amazed even the best of university students. Some one, for instance, came to ask him to repair an organ. He did not decline because he had never repaired one. He took to studying not only the mechanism of the organ but of the whole range of musical instruments. He solved musical problems that troubled the greatest scientists in Europe. Violins, cellos, organs,

guitars, flutes were produced by him. He invented many devices for the organ. From all sides work poured into his little shop.

Yet the vision of the steaming kettle still fired his imagination.

There was in existence a machine called the Newcomen engine. It was used to pump water from collieries and mines. It worked by steam, but was so dangerous and inefficient that it was of little use. Watt examined it, and to himself put the question, "How does it work, and can it be improved?"

He carefully studied the Newcomen engine. He found that it worked as follows. Steam from a boiler was sent into a cylinder. The steam expanded. It then pressed up and, aided by a counter weight, raised the cylinder, to which was attached a beam. To cause the cylinder to drop down again, cold water was jetted on it. The steam was thus cooled and condensed into water again. Then, since there was no more steam to press upon the cylinder, the cylinder fell down and so did the beam. Then the water had to be let out of the cold cylinder and steam sent into it again. In this way, the beam was caused to move up and down and do work.

Watt easily saw that this was a slow process. The trouble lay in the fact that the steam, condensed by the water, so cooled the cylinder that when the next charge of steam was introduced, four-fifths of that steam was used in making the cylinder hot, and only one-fifth of it in moving the beam.

"If only the cylinder could be kept always hot!" thought Watt.

He was walking in the country one day, pondering over this obstacle, when suddenly the solution flashed into his mind. A separate chamber where the jet of cold water could condense the steam, leaving the cylinder always hot!

Home he rushed. He borrowed a syringe, found a tin can, and set about making a model of a new steam engine.

He rented a cellar, and for six months labored over his model. In order to study the subject thoroughly, he learned new languages — German, French, and Italian, because there were books on engines in those tongues that he ought to read. But he did not rely on books alone. He was too good a scientist to do that. Since he was studying the nature of steam, he made clouds of it in his shop. He compressed it into small bottles, he let it expand in big ones. He watched steam behave in all sorts of ways, and discovered things about it that no other scientist knew. At length he was ready to build his engine.

A new era dawned. The new engine began its career by being a hundred times more efficient than the old. To-day Watt's engines in any large factory do the work of as many as five million men under one roof. It does not matter what the work is, the engine can do it — it can pull, drive, turn, hammer, shape. The steamship, the locomotive, the automobile, are all Watt's engine grown up. And that all people now can have the luxuries that once only princes could afford is due to Watt's steam engine.

The inventor realized the great possibilities of his engine. Ideas for steamboats and locomotives were straining in his mind, but he had no time to let them out. Yet largely to James Watt we owe them both. But we owe more! That we have the leisure to read and study and are not forced to labor twelve hours a day in a factory is largely due to James Watt.

II

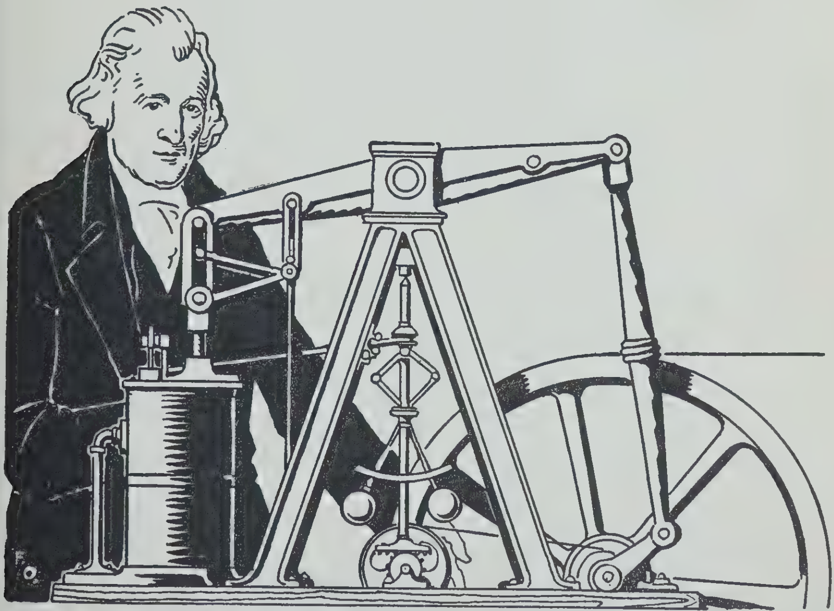
There are few days so illustrious in history as the fifth of January, 1769. It was indeed a happy day for the human toiler; for on that day Sir Richard Arkwright received his

patent on the spinning jenny, and James Watt his patent on the steam engine.

Yet Watt's troubles were far from over. They, in fact, had just begun. To manufacture engines requires money; to continue study and experiment, more money. So he had to work as a surveyor and engineer to support himself.

Like Lavoisier, he solved the water problem for a city, the city of Glasgow. And throughout his daily labors, his mind teemed with other scientific ideas and inventions.

At last, by 1776, his engine was acclaimed by everybody. The eyes of the world were upon him, and he could call himself successful. At the height of his powers now, he



James Watt realized the great possibilities of his engine.

gave shape to all his schemes. Inventions of all kinds came from him in profusion: a copying press still in use to-day, a drying machine, a new micrometer, a new surveying quadrant, a drawing machine, a copying press for sculpture,

astronomical instruments, — these are only a few of his gifts to humanity.

"Gimcracks!" he called them modestly, and so fast did he turn them out that one of his friends once greeted him by saying: "I daresay you have invented, since I saw you, five hundred engines."

There was a club of scientists in Birmingham, called the Lunar Society. Once a week they met at two o'clock in the afternoon and parted at eight in the evening. In the meantime they talked pleasantly on every conceivable scientific subject, and the center of attraction was Watt, for everything in the book of Nature and Man was his study. To his friend Sir Walter Scott, he talked about the writing of novels. To a friend who was a student of languages, he talked of the origins of the alphabet. He might advise an artist on the best hair for brushes, or a housewife on the cure for a smoking chimney, or a musician on playing a dulcimer. His mind, like his steam engine, could do anything.

His favorite science was chemistry, and as a chemist he was one of the best of his time. When he was in Paris, he visited Lavoisier, with whom he found he had an unexpected bond. Before the two scientists met, each had discovered, unknown to the other, that water was composed of two gases. That fact must have made the two chemists great friends.

Every learned society in Europe paid him tribute; every academy honored itself by electing him a member. The governments of Russia and France both offered him handsome posts, if he would only consent to live in their countries. For a while, English scientists were alarmed lest they lose him. He stayed, however, in Scotland.

The heart beats faster to think of him as an old man, still working in a garret to lighten the labors of men; a kindly old man, unassuming and generous, ready to en-

courage any young person applying to him, conversing with equal knowledge on every subject conceivable — languages and literature, science, medicine, law, music — and with a modest courtesy that has made him one of the most beloved characters history has known.

His work was done. OnAugust 19, 1819, he left the world richer a millionfold than when he entered it. The world's tribute to James Watt is expressed in a colossal statue of him in Westminster Abbey which bears the inscription:

Not to Perpetuate a Name
Which must endure while the Peaceful Arts flourish
But to shew
That Mankind have learnt to honour those
Who best deserve their Gratitude
The King
His Ministers and Many of the Nobles
And Commoners of the Realm
Raised a Monument to
JAMES WATT
Who directing the force of an Original Genius
Early exercised in Philosophic Research
To the Improvement of
The Steam Engine
Enlarged the Resources of his Country
Increased the Power of Man
And rose to an Eminent Place
Among the Most Illustrious Followers of Science
And the Real Benefactors of the World
Born at Arunock MDCCXXXVI
Died at Heathfield in Staffordshire MDCCCXIX

SIR HUMPHRY DAVY

(1778–1829)

The Poet-Chemist

I

SOMETHING over one hundred years ago families in the mining regions of England were in a state of terror and anguish. The bitter wail of mother and child was striking to the heart of the world, as the shattered bodies of their men-folk were almost daily brought home to them. From every mine and colliery, the news of disaster upon fresh disaster stunned and halted the progress of civilization; and the bereaved ones, thrown into dire poverty, became everybody's concern. The explosions in the coal mines, it seemed, could not be checked, and miners seemed doomed to annihilation.

On May 25, 1812, ninety-two men and boys were killed by an explosion in a mine. In another mine eighteen months later, twenty-three were killed. Over a year later fifty-seven more were mangled to death. Then again the same number, and this list of tragedies was being repeated in all mining regions of England. The country was in despair. Many mines were shut and it seemed as though industry itself was about to die.

The mine owners, in the summer of 1815, decided to appeal to Humphry Davy who, at thirty-seven, was the greatest living chemist. The Welsh chemist was then traveling in England and the appeal was made to him by letter. Davy was informed that in the depths of mines there

lurked a malignant gas which caught fire from the miners' candles and exploded. Could anything be done about it?

Very shortly after the letter to Davy was sent, Mr. Buddle, a mine owner of Bristol was brooding anxiously in the office of his Walls-End Colliery, when two visitors were announced. One was the Bishop of Bristol, who presented Mr. Buddle to his pleasant-faced young companion.

"Mr. Davy," he said.

But Mr. Buddle was by no means overcome with joy. On the contrary his gloom continued. He did not see that anything could be done to relieve the tragic plight of the miners.

"You see, sir," he explained, "wherever we mine coal, gas gushes out of the coal bed. That situation is critical, for the gas is explosive and we miners must have light to do our work. We must use light," he repeated, "and all around in the mines is gas steaming from the rock. It is hopeless."

Humphry Davy listened thoughtfully. Then he began to question Mr. Buddle carefully on the exact working conditions in the mines, the nature of the gas, how it hissed from the breaks in the rock, and whether or not he could take back with him samples of the gas. On being assured that he could, he arose, and looking keenly at the dejected mine owner, said, "I think I can do something for you."

Mr. Buddle glanced up incredulously. Davy, however, smiled. "Do not despair," he said kindly. "I think I can do something for you in a very short time."

Two weeks passed. Then one day a package came from London to Mr. Buddle. It contained a new sort of lamp and a letter from Davy.

"I flatter myself," wrote the chemist, "that this lamp I have invented will answer your purpose. Try it."

Mr. Buddle was skeptical. He was also desperate. Calling together a few of his miners and showing them the lamp, he bade them prepare for a descent into the mine.

"Surely, sir," protested one of the men, pointing with contempt at Davy's lamp, "this will not save us from being blown to pieces." And a chorus of voices took up the protest.

"Nevertheless," said Mr. Buddle firmly, "we will test the lamp, danger or no danger. I shall lead the way."

By this time, the wives of the miners had collected, and their lament and wailing were so great that it was only by physical force that they could be kept off. At last the men were lowered into the pit of the mine where they expected to meet with instantaneous destruction. Indeed, their dread was so great that the slightest noise terrified them. Suddenly the hiss of the gas was heard.

"Let us go back!" the men implored. But even as they spoke, the gas swept over the flame of the lamp. It swept over . . . and the flame but burned the brighter for it.

On went the little party, carrying their lamp high like a banner, with new courage in their hearts.

"The monster is destroyed," said Mr. Buddle exultingly. "The Davy has saved us."

The name stuck. A miner at work to-day would as soon part with his life as with his "Davy."

Some time later, Humphry Davy himself visited Mr. Buddle again.

The mine owner tried to express to the scientist the gratitude and the jubilation that the world felt.

"But, Mr. Davy," he wondered, "is it not remarkable that so simple an instrument can defy an enemy heretofore unconquerable?"

Davy laughed. "It is simple," he agreed. "But it serves. When I examined the samples of the gas, or fire damp, I found that the gas exploded violently only when it mixed with a great deal of air — seven times its own amount, in fact. It burns by the help of the oxygen in the air. So, by uniting with the oxygen and thus taking it from the air, it

makes the air unbreathable. Then, to add to the danger, it explodes. In this way, I saw that air and fire damp should be kept away from each other. The first thing I had to do, therefore, was to make it impossible for much air to enter my lamp — though I needed some air, because, as La-

On went the little party, carrying their lamp high like a banner.

voisier showed, a flame will not burn without the oxygen of the air. I finally hit on the idea of allowing the air to enter only by all these very small tubes you see. By this means, only the meager amount of air that the flame needs can enter.

"Besides, I further discovered that the gas explodes only when it is very hot. I was afraid that if, by accident, enough air and gas did combine, the metal sides of my lamp would be hot enough to set fire to the mixture. So I had to think

of a way to draw off some of the heat from the metal of the lamp. Do you see all the wire gauze around the flame? That gauze uses up part of the heat, so that the sides of the lamp can never grow hot enough for the gas to explode. Yes, it is a simple instrument."

As a token of their gratitude, the mine owners presented Davy with a dinner service of silver plate worth about $6000. In his will he stipulated that the silver should be melted and sold, and the proceeds be devoted to founding a medal to be given annually for the most important discovery in chemistry. The Emperor of Russia sent Davy a vase; and the King of England shortly after conferred on him the title of baronet.

A friend of Davy's urged him to patent his lamp, and make money out of it.

"My good friend," replied Davy, "my sole object was to serve humanity, and if I have succeeded, I am amply rewarded. I have never received so much pleasure from any other of my chemical labors, for I trust the cause of humanity will gain something by it."

Like Lavoisier, Davy was more the friend of mankind than he was man of science or of business. Even before he invented his safety lamp, the name of Davy was known in the scientific and social world. But afterwards, in every cottage, however humble, the name of Sir Humphry Davy was like a charm.

II

The rise of Davy was all the more brilliant in that he had not had much schooling. At the age of seventeen he was apprentice to a surgeon and apothecary. The strange liquids and powders about him in the laboratory fascinated him so much that he would take them to his garret and there mix them, burn them, taste them, shake them, do

this and that, and generally alarm his mother with the rich smells and sudden sizzlings. His sister's dresses showed the effects of his experiments, and his mother was warned that he would some day blow her and everybody around to shreds.

But he was not playing idly in his experiments. Lavoisier's "Elements of Chemistry" was his constant guide. So skillful a chemist did the lad become, in fact, that Dr. Beddoes heard of his talents and engaged him as superintendent of his hospital in Bristol.

There the young chemist became interested in gases of all kinds. He thought patients could perhaps be cured by inhaling the proper gases, if he could only discover them. In his small laboratory, he was constantly risking his life by inhaling various gases that he manufactured. On one occasion he was found unconscious, and with great difficulty brought back to life.

One day, after breathing quantities of a peculiar gas which he had just discovered, his friends were amazed at a certain change in him. For no apparent reason, he began to dance. And dancing, he began to laugh hilariously. He could not control the gales of laughter that shook him, until he suddenly subsided and fell into a long deep sleep, Davy had discovered laughing gas, which was later to become so useful in dentistry.

His fame spread abroad. Encouraged by his success, he became interested in the general questions of science. For instance, despite Lavoisier's proof to the contrary, it was still widely believed that fire or heat was a distinct substance like wood or stone. "Wood burns," it was agreed, "because it has in it a fire substance which rushes out."

Of course all scientists did not believe this. Count Rumford, for one, in his lectures at the Royal Institution in London, said that heat was not a distinct substance. "It is known," thought Count Rumford, "that amber when

rubbed, becomes magnetic. With heat, it is the same way. When the swarms of tiny steel particles are excited, the steel grows hot. We cannot, with our eyes, see the specks of steel dancing about heatedly, but it is surely the dancing which makes the steel hot."

In Bristol, Davy heard of the count's idea, and it seemed reasonable to him. But how could it be tested? Like a good scientist Davy always looked for the test. One day it came to him. In freezing weather he took two pieces of ice and began rubbing them together. The result was victory; instead of ice, he soon had a small pool of water.

Elated by this proof that rubbing or exciting the bits of ice, will heat them and melt them, he wrote to the count about it. The gratified answer came shortly, and with it — it took the youth's breath away! — an engagement to lecture at the great Royal Institution at London, and Davy only twenty-two years old!

But he was as brilliant as he was young. For twelve years he remained with the Institution, amazing the scientific world with one discovery after another. He seemed to be capable of anything. No matter what the nature of the chemical mystery, Davy could clear it up. He was required by the Institution, for instance, to lecture on agriculture. "I know nothing about it," objected Davy. Nevertheless, he was ordered to try. With study, he soon became its greatest living authority, and published a book on the chemistry of agriculture.

The city of London was so amazed at the natural wonders of chemistry as Davy showed them at the Royal Institution, and so smitten with the charm of the young scientist, that it became fashionable for the ladies and gentlemen of London society to frequent Davy's lectures as they might a theatre.

One morning, when they had assembled in the lecture hall, they noticed Davy and his assistant busy with a box-

like apparatus on the table. Wonderingly, they looked at it. What could it be? Suddenly Davy nodded to his assistant, who touched something. The audience gasped and stared with open mouths at a chain of white light that had burst from the box and was crackling brilliantly in the air.

Davy, the magician, stood near the column of light, watching it keenly. "This is the light from electricity," he announced.

He reached under the table and drew out a small magnet with which he began to make passes at the crackling stream of light. The light bent. No matter where Davy held the magnet, thither the light curved, writhing and dancing under Davy's direction.

In this way Davy produced the electric arc light for the first time in history. To-day it is a common enough sight because of Edison's invention of the electric bulb, but in those days it seemed like a miracle from heaven.

Davy was delighted with his electric battery. To try out the effect of electricity on the human body, he used to send the current through different parts of his own frame. He was, indeed, very strongly attached to his battery. When his tongue was attached to it, a sour taste filled his mouth. When his eye was attached, he saw a flash of light.

"I feel a shock," he told the members of the Royal Institution, "then a numbness and a tingling sensation."

One illustrious day, he sent a current of electricity through two glasses of water. At once, bubbles of two different gases began to form, and the water to disappear.

"Lavoisier was right," Davy told his audience. "Water is a compound of two gases — hydrogen and oxygen. The electric current has broken the liquid up into its two parts."

"Now," reasoned Davy, "if an electric current can break water up into its simple elements, it can do the same to other things." He knew that most things are like water,

in that they consist of several elements united in one body. A club of men is like that. One member is a doctor, another a lawyer, and a third, a business man; they meet and form a club. Just so, water is a club of two members. And Lavoisier was the great detective who discovered the members.

Our world is made up of countless clubs of elements, and Davy determined that with his powerful battery he would break into as many clubs as he could and find out who the members are.

He began with a rather homely sort of organization — potash. He melted the potash in a spoon, and connected the spoon with his battery. At once a beautiful sight appeared. A vivid light glowed at the tip of one wire of his battery, and at another point a column of flame arose. As Davy watched, the liquid potash began to bubble, and in the spoon shone tiny globules. They looked like droplets of quicksilver, but they were not.

"A new element! The tiny globules are a new element!" cried Davy, dancing around like a happy lunatic. "Potassium!" he called the element.

A few days later he discovered sodium in the same way, and in the days following he added four more to the list of elements. To-day we know of ninety-two elements that compose our universe of clubs.

III

"If Davy had not been the first chemist of his day, he would have been the first poet," wrote Samuel Taylor Coleridge, one of our greatest English writers and a friend of Davy. Coleridge attended the great chemist's lectures at the Institution for the sake of hearing the rich metaphors that Davy used with glowing eloquence. Nor was Coleridge the only literary man to admire Davy's poetic

talent. Robert Southey, appointed poet laureate of England in 1813, when doubtful of one of his poems, wanted no better criticism than Davy's opinion.

At the height of his career, Napoleon Bonaparte offered Davy an honorary prize. England and France were then at war and many narrow-minded Englishmen spoke to Davy warning him not to accept the prize from the "enemy of his country." But Davy was reasonable and accepted the prize. He, who had saved the lives of the miners of France as well as those of England, said, "If two countries are at war, men of science are not. We should, through men of science, soften national hostility."

Like all our heroes, Davy never ceased working. In his efforts to serve the cause of science, which gives people the good things of the world and an understanding of life, he overworked and fell ill. Death itself he did not fear. But he was always afraid he might die before finishing the experiment on which he was engaged.

In Rome in 1826, paralysis crippled his right side, but he worked on as best he could. Even on the day of his death, May 29, 1829, like Galileo, his last concern was to leave directions for the completion of an important experiment.

MADAME MARIE SKLODOWSKA CURIE

(1867–   )

A Matter of Mystery

I

IT IS the year 1200. In a gloomy cell an old man in a skull cap is working feverishly. A smoking crucible is in his hand, and his eyes fairly start from their dark sockets as he peers into it. Is there a glitter as of gold in the vessel?

All his life he has been looking for that yellow gleam. Some people call him a charlatan. Others revere him as a philosopher. Nothing, however, can shake his faith in the belief that lead can be changed to gold. Only . . . the world is growing tired of waiting, and he himself — unless the elixir of life is soon found — will not need gold.

The actor of this scene is an alchemist, the ancestor of the chemist. He stakes his reputation on the principle that at bottom all things are one and the same, and that therefore lead is the same as gold — if one can find the secret of the shiny disguise.

The scene might serve as a prologue to the greatest drama of the scientific stage — "What are things made of? What is the stuff that we touch and see all about us?" It is the oldest of questions, and every thinker has offered his opinion on it.

"Nonsense!" once sneered the common man. "It is a foolish question to ask. You know well enough that water is water, and that air is air. They are not made of anything but themselves."

Then came Lavoisier and showed that water is really a compound of two gases, hydrogen and oxygen, and that air is a mixture of several.

"Very well," was granted grudgingly. "But you can't go any further. Our world is made of hydrogen, oxygen, and a few dozen more elements."

But scientists did try to go further. "What are hydrogen and oxygen and all other elements made of?"

One day in the year 1880, William Crookes, an English chemist pumped most of the air out of a glass tube. Then he sent an electric current through the tube. To the amazement of Crookes, one end of the tube began to glow with a queer light.

"What causes these rays of light?" wondered Crookes. "And what are the rays made of?"

Idle wonder was useless. He must trick the rays into speaking for themselves. The ruse was simple. Into the tube he put the tiniest, lightest vane. Now as the mysterious rays fell on the vane, they answered one of Crookes' questions by making the little vane pirouette about and grow hot.

"As you see," said the rays in effect, "we are millions of solid particles streaming ahead with all our might, knocking down everything in our way."

But where do the particles come from and why do they clash about so? There was only one source — the little quantity of air in the tube. But . . .

And there the matter stood.

The next scene in the great mystery takes place fifteen years later in the laboratory of a German professor of science, Wilhelm Konrad Röntgen. He is repeating the experiment of Crookes, but for variation he has thrown a curtain over the tube. The professor's table, by the way, is littered with all sorts of things. "Careless and absent-minded!" he is called. But this time it paid to be careless,

for in the welter of tubes, chemicals, and papers, there is also a photographer's screen.

The professor starts the current through the covered tube when, for no apparent reason, the plate on the table begins to shine brilliantly. What is the connection? The professor turns off the current in his tube; the glow on the plate subsides. There is some force in the tube, concludes the professor, that can pass right through a heavy curtain. There are unknown rays — X rays he calls them — in the tube. So powerful are they that they pass through solid opaque matter, as the sun's rays pass through a pane of glass.

To suffering mankind, X rays, or Röntgen rays, have been an exceedingly great boon. No longer need the dentist pull the wrong tooth! X rays will show where the infection is.

But not all scientists cared what X rays would do for toothache. "What are these rays?" they wondered rather. They suspected that things are not what they seem; that Lavoisier and others, indeed, did not go far enough when they found hydrogen and oxygen and the other elements which they said made up our world. Hidden in all things, it was suspected, was the secret stuff of the universe. And those mysterious electrical rays seemed to be visions of that stuff. Every scientist began to study rays of all kinds, feeling that perhaps in them lay the answer to the riddle of nature.

Then came a remarkable discovery by a French scientist. He found that rays need not be manufactured. Nature has a ready supply of them in the form of a certain mineral called uranium. This gives off rays so powerful that they can penetrate even a sheet of metal.

The discoverer rushed off to tell his friends, Professor and Madame Curie, about the great find — and here the heroine enters on the scene of this great scientific drama.

II

Marie Sklodowska was the motherless daughter of a Polish professor of science in Warsaw. Her love for her father and reverence for his calling as a scientist made it a keen joy for her to help him in his laboratory. With the same fascination that she herself was later to exert on her hearers, she listened daily to his talks with students. Even in the gray days when their poverty had been a source of suffering, she lived in the romance of science and saw the magic in strange chemical adventure. But it was the strange magic of truth, and a romance so real that she never felt the poverty of her home.

Nor did hardship daunt her any the more when she was a grown young woman, alone as a student in Paris. Far from home and frequently having to make a meal of bread and milk, she was amply nourished by dreams of becoming a scientist and doing her share for humanity. For a long time she could not get work. Then one day a professor of the University of Paris allowed her to work in his laboratory. It did not occur to him that she was of any value as a scientific worker; the duties he assigned her were those of a caretaker in his laboratory.

The young assistant, Pierre Curie, was not so blind. He admired her courage and her enthusiasm for science. As for Marie Sklodowska, she must have been attracted by the mind of young Curie, a scientist already winning the respect of scholars. They spoke of the possible adventures in science, or of how the world could be made better.

"It would be a lovely thing," said Pierre one day, "for us to pass through life together with our dreams: our dreams for humanity, our dreams for science."

That was the beginning of that great partnership of two scientists whose glorious struggles have revealed the most amazing thing in our world since the days of Galileo.

III

When Madame Curie heard from Röntgen of the queer behavior of uranium, and all that it might mean, she decided to devote herself to the study of it. Her husband, meanwhile, was hard at work on the study of crystals, a work for which he became famous.

Now uranium is taken from an ore called pitchblende. Madame Curie's first task, therefore, was to extract the uranium from a lump of pitchblende. The uranium out, the rest of the ore was supposed to be useless and uninteresting. When Madame Curie had extracted the uranium, however, she made her first discovery, that the pitchblende, supposed to be worthless, still gave off rays.

"There is something startling here!" she told her husband. "There is hidden in the remaining pitchblende a force vastly more powerful than has ever been known. If I can only extract it!"

At this Pierre Curie could not restrain his excitement and, leaving his crystals, joined his wife on her road of discovery. But at the very outset they were handicapped, they needed great quantities of pitchblende. Exactly how much they did not know, for they could not tell where their experiments would lead. Certainly they needed more than they could afford to buy.

The largest mines of pitchblende were at that time owned by Austria, and the Curies decided to appeal frankly to the Austrian government. Were they not working for common humanity? The Austrian government responded generously with a gift of a ton of pitchblende, and the Curies began their exciting search. With the greatest zeal and patience they went to their task. It was no easy one. They might have honestly given up in discouragement, for as time went on, they used up almost all their pitch-

blende without discovering a single trace of what they sought.

Was it all a dream then, that there was a strange, new substance to be found?

One day, under the fingers of the searchers, an unknown force came reluctantly out of the pitchblende. Its rays were more penetrating than anything yet discovered. It revealed the inside of bodies of wood and stone more vividly than had ever been imagined possible. Polonium they named the new element, in honor of Madame Curie's native country, Poland.

"Our long search is ended," they thought. But no! The residue had still greater powers, and the Curies went back to their task of getting to the core of this radiation. After years of work came their greatest discovery. A pinch of grayish white powder, looking like salt, was all the Curies had to show for a ton of pitchblende and years of work, yet it brought about a revolution in our ideas of the world. That powder was radium, and its strange glow, like a firefly's, brought about the great change.

Some of the rays, shot out of radium, consist of particles traveling almost with the speed of sunlight — 186,000 miles in one second.

"But what are these particles?" it was asked. "If they are bits of radium, then radium is spending itself so rapidly that we should see the last of an ounce of radium in a short time."

Yet it takes over 100,000 years for an ounce of radium to spend itself. How many countless billions of billions of these particles there must be in an ounce!

The imagination of scientists began to stagger at the idea of such numbers. But more than that, what amazed everybody was that Nature seemed to be an alchemist. They learned that radium passes off in a shower of rays,

and that it changes from stage to stage, until finally it becomes the metal, lead.

IV

Was the alchemist of the Middle Ages right then? Could one substance be changed to another? Ernest Rutherford, an English professor of chemistry, "bombarded" the gas, nitrogen, with some of these mysterious rays. Using those particles as bullets, Rutherford shot them into the nitrogen. The alchemist *was* right.

This experiment of Rutherford told a startling tale. Everything — you, the paper you are reading, the stars, the trees, your house, your dog — everything in the universe is made up of particles we call electrons and protons. An electron is so small that to us who are not scientists it seems to have hardly any size or weight. It takes billions of them to cover a point.

Now electrons are rather snobbish in their habits. Each one belongs to its own group or atom. The only difference between the groups is in the number of members. An atom of gold, for instance, has 79 electrons in it, while an atom of copper has 29 electrons. But except for the number and arrangement of electrons and protons in them, there is no difference whatever between the atoms of gold and those of copper or of your dog, if you please.

That explains why Rutherford was able to change nitrogen to hydrogen with his bullets. He knocked a few members out of the nitrogen group — just enough, in fact, to make the remaining number of members equal to the number in the hydrogen group.

A similar thing happens to radium. The atoms in that element are constantly breaking up. The electrons are flying out of their element, hitting the air and everything else right and left, and we see the results as rays. Other

things, like a table, for instance, have their energy locked up and do not give it out. But radium discharges its force.

An astounding picture! No wonder the imagination reels. But the final fact, bound to make one gasp in awe, is the distance between an electron and its fellow member. Rutherford was puzzled; before he was able to hit a single electron, he had to fire thousands of his invisible bullets into the nitrogen gas.

"The reason must be," he thought, "that there are few electrons to hit. Matter is porous. I am shooting blindfolded into a field where there are only a few targets. Our universe is mostly holes, and as empty as a ghost."

In that sense we human beings are ghosts in a ghostly universe. In fact, if all the solid matter in a man's body was pressed together, it would be just about visible under a magnifying glass.

Truly we live in a world compared to which the wonderland of Alice is a humdrum affair. And perhaps the greatest mystery of all is the mystery of matter.

V

The world hailed Professor and Madame Curie with honors. They were given the Nobel Prize for physics in 1903. Madame Curie was appointed special lecturer at the Sorbonne in Paris, the only woman ever to have had that distinction.

One day a terrible sorrow visited Madame Curie and the world. The former lost her beloved husband; and the latter, a great man. Pierre Curie was the victim of a fatal accident.

The bereft woman still had her work, even though she must now do it alone.

For with the discovery of radium, a new world of possibilities opens before us. Aside from the glimpses into the

Madame Curie was appointed special lecturer at the Sorbonne.

real world of matter that radium affords, it turns out to be an invaluable ally in relieving human suffering. Its very breath is destruction to the most deadly of germs. It even promises to drive out that terrible scourge, cancer, before which we have been so helpless these many centuries. The gas from radium, bottled and applied to the diseased tissue, heals and saves.

Only, one must be very careful in using this powerful gas. Pierre Curie was the first to show the danger of it. How? By exposing his arm to it for several hours. The result was a wound for Pierre Curie which took months to heal. But what cared he? The world knows as a result how radium acts on the human body.

Madame Curie has carried forward the task that once was partly her husband's. In 1911 she was awarded the Nobel Prize again, this time for chemistry.

An American who visited Madame Curie recently was greatly surprised to find her rather poor — at least, far from rich. So many men have been made very wealthy by the discovery of radium that the visitor was surprised at the circumstances of the discoverer herself.

"The money on your patents . . . " she suggested.

"There were no patents," replied Madame Curie quietly. "We are working for science. Radium is an element. It belongs to all people."

ALBERT EINSTEIN

(1879–   )

The Theory of Relativity

I

THERE were never two men more astounded than Professors Michelson and Morley in the year 1887.

"There must be a conspiracy of Nature against us," they protested.

The cause of their astonishment was a most delicate experiment: to determine how fast the earth travels. Scientists knew already with what speed the earth revolves around the sun. Now Professors Michelson and Morley wanted to know how fast the earth is traveling on its own way through space.

If at that time Professor Albert Michelson had been asked by one of his students how he could determine so daring a question, what an amazing reply he would have received!

"It takes a swimmer a longer time," was Michelson's thought, "to swim against the current than with it. That seems like common sense. But here is the case of a swimmer that acts differently. The swimmer is a beam of light. In my experiment I find that it takes a beam of light just as long to go out a certain distance as to come back. Whether it goes to the east or to the west — no matter in what direction — always I get the same answer, that light

acts as though the earth were stationary. Must we then say that the earth does not move through space?"

That was the dilemma in which Professors Michelson and Morley found themselves.

"But this is impossible," every one cried. "It would mean that for three hundred years we have been deceiving ourselves. It would mean discarding Copernicus' and Galileo's theories, and many of our hard-earned scientific gains, and going back to Ptolemy and the Chaldean shepherds." The experiment was repeated, more accurately than before, but with the same result: the earth is stationary. New and ingenious experiments of different kinds were tried. Again the same result. Was Nature playing a game, in one breath telling us of our motion through space, in the next denying it?

That was the state of affairs, until a remarkable wizard stepped forward and solved the mystery. The wizard, Albert Einstein, was only twenty-six years old at the time of his discovery, and working as a modest clerk in the Patent Office at Zurich, Switzerland.

II

People of the little town of Ulm, in Germany, must indeed be proud to remember the lad who was born there May 14, 1879. He was of a shy, dreamy habit, given over even at an early age to solitary contemplation. While his schoolmates were at boisterous play, he might be seen alone in his father's garden, humming to himself little songs he composed.

When Albert was five years old, his father showed him a compass. The swinging needle awakened in the child a great wonderment as to what mysterious force caused the needle to move. That wonderment he was later to feel for the entire realm of nature.

At school Einstein, like Newton, was an indifferent scholar; at least, his teachers saw him so. The reason may have been that the Munich schools which he attended, like all the German schools at that time, were far from pleasant. They were like military academies, where the pupils were soldiers and the teachers, officers; or like jails, with the pupils feeling like convicts and the teachers acting like jailers.

One day Albert heard the word algebra. It was a curious word, so he asked his uncle, an engineer, what it meant.

"Algebra," said his uncle, "is a lazy man's arithmetic. If you don't know a thing, call it X, and act as if you do know it."

That was enough. Before long, Albert had solved all the problems in an algebra book his father gave him. And when his friends were still grinding on decimals, Einstein was in the beauties of calculus. His teacher of mathematics declared that the fifteen-year-old boy could easily enter the second year of college.

In 1894, his family moved to northern Italy. For a while, the joys of mathematics yielded to the glories of nature. The rugged peaks of the Apennines, the wild majesty of cliff and mountainside, beckoned the youth. Alone, he wandered about the country, sometimes extending his excursions far from home. He breathed freely. The liberation from the rigid discipline of the Munich high school, the freshness of Italian landscape, the gayety of Italian life — all fed his imagination.

For six months he was free from school. Having laid aside his text books, he dipped at will into literature. At length, however, it was necessary to think about preparing himself for the university. To this end, he traveled to Switzerland, where he was finally enrolled at the Zurich Polytechnic Institute.

Here he no longer was the indifferent scholar of the

public school. Already he was showing astonishing originality in mathematics and physics. We get hints that in these years Einstein concerned himself with problems which were later to clear "the conspiracy of Nature", which confronted Michelson and Morley.

He wanted to be a teacher, for he sought refuge from the world of rivalry known to business. Ambition for money or power was hateful to him. He could not serve either humanity or himself by such means. As a teacher he would find peace and be able to perform a duty he respected.

He was, however, unable to secure immediate appointment as a teacher and, for the time being, he earned his living as a clerk in the Swiss Patent Office, in his spare time working on his science and mathematics.

III

Everybody was still bewildered by the Michelson-Morley experiment when suddenly Albert Einstein presented an explanation which burst like a bomb in the midst of our peaceful science, upsetting all our old ideas.

Let us recall what the Michelson-Morley experiment seemed to show. Apparently the earth is standing still, yet we know it is moving around the sun!

Certainly, said Einstein. It is doing both. It all depends on how you look at it. Suppose you were born and brought up in the cabin of a large ocean liner, say one of those powerful vessels that travel through the waters smoothly. Suppose, too, you were never told you were on a ship or that there was such a thing as an ocean.

As you sat in the cabin room, you saw your father move about from one part of the room to another. The walls of the room, however, did not move. Only your father moved when he changed his position.

You are reading a book. All at once, the book drops from your fingers. Thud! Straight down at your feet it falls.

Now suppose you have a startling adventure. Your father has by accident left the cabin-door open and, overcome by curiosity, you step forth and find yourself in a strange world — the deck. In amazement, you peer over the rail of the ship into the water and observe that the ship is moving across the water, just as your father moved across the room.

Your ship is approaching a promontory of land. Roused further with the spirit of adventure, you run to the prow, and as the ship is gliding by, you spring from it to the cliff. You turn around just in time to get a last glimpse into the cabin. You see your father drop a book. Does it seem to fall straight down this time?

No. The cabin is moving; therefore everything in it is moving, too. The book, as it falls, moves not only downward but forward. Does the book fall straight? Yes and no; it depends on whether you are inside the cabin or on the land looking into the moving cabin.

Now tax your imagination heavily. You are on the sun, and by some miraculous spyglass you look into the same cabin. How does the book appear to fall?

It falls down; then forward because the cabin is sailing on the ocean; then in a curve because the earth is moving around the sun and so around you. If you were on the star Vega, furthermore, the falling book would have another motion because not only our whole solar system of which the sun and the earth are a part, but also the star Vega is in motion.

Now, says Einstein, all nature is in continuous motion. How can we tell it? By comparison only. Suppose one day you board the train for the seashore. You put your suitcase up in the rack, sit down, and think what a pleasant time awaits you. Hours, so it seems to you, elapse.

"Why doesn't the train start?" you exclaim impatiently, and look out of the window for the cause of the delay. To your delight you find yourself gliding by the windows of another train.

"We're off!"

You are not able to tell that until you compare your train with another. Suddenly, to your dismay, you find it is the other train that is moving. Now how do you find that out? By comparing your train with some telegraph poles. Too bad! And you were enjoying the ride so!

Suppose, for instance, that some demon began to shove telegraph poles past your window at the rate of sixty miles an hour. What an hilarious ride you would be having! Of course, you would never get to the seashore, but that has nothing to do with the fact that you would seem to be moving, and at a great rate, too.

"All motion is relative," says Einstein. "You can never discover the motion of the earth unless you compare it with some other body in the heavens. Since Professors Michelson and Morley did not make the comparison with any object in the heavens, they could not find the earth moving.

"There is another mistake we have always made," Einstein further pointed out. "We've always thought that objects have three dimensions — length, width, and height. But there is one other we've overlooked. Wrapped up in every object somehow, there is the fourth measure — time."

"Time!"

"Surely. Just think! If we made an appointment to meet, you would think it too casual or rude for me to say only, 'We'll meet on North Main Street.' You would want to know where on Main Street. 'East Fifth Street,' I then specify. 'Which corner? What floor of the building? And one other thing — at what time?' you ask."

"Again, if you were teaching some one a tune on the piano, you would have to show your pupil *where* on the piano the note was, and how *long* to hold it. We cannot have music without time.

"Up in the sky there is a startling illustration of how time is one of the four measures of things. Alas for the poet who gazes enraptured at a gleaming star! The star is not where it gleams. The poet should know that the only way we can see a star is by the light it sheds. Now some of the stars are so far away that it takes their light thousands of years to reach our eyes. Meanwhile the star moves on, and is no longer where we see its gleam. So time, which deceives the poet in regard to his star, is an important part of the world. Of course, we can not see time with our eyes, but we have other senses besides sight."

Here was something new. In our whirling universe, the book in your hand and the sun in the sky both have length, width, height, and — time. You cannot gaze on the time-size of an object with your eyes. So you can not see what a grotesque world you live in.

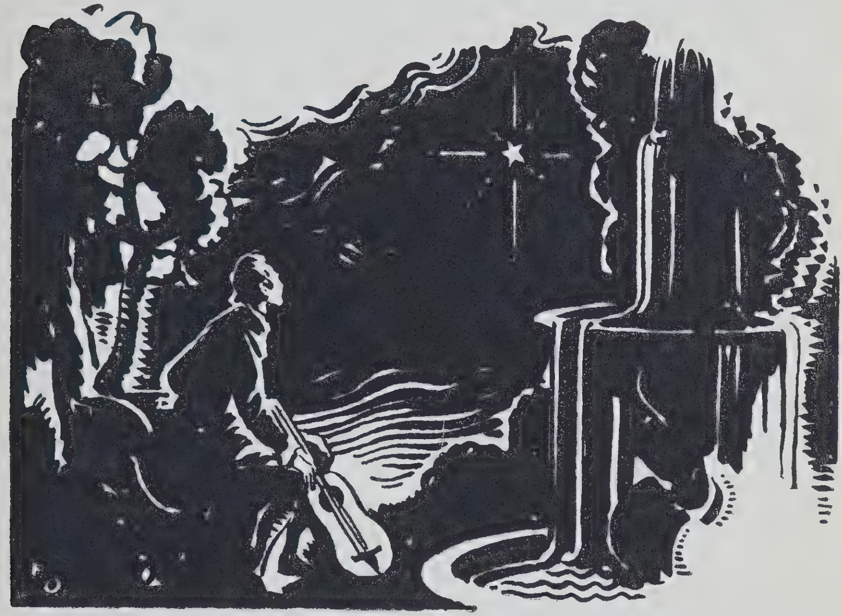
Grotesque indeed! "We live in a world which is curved," says Einstein. "For instance, the moon turns around the earth. We say the earth pulls it. But it is simply that around the earth our space curves, and the moon has no choice but to move in a curve."

Suppose you were told of a room where all the marbles that you laid on the floor rolled down to the center. If you believed with Newton, you would say, "There is a force in the center of that floor — the force gravity — that pulls the marbles down."

But if you thought like Einstein, you would reply, "Perhaps there is another cause working with gravity. Perhaps those marbles also roll naturally. Maybe the floor is curved."

To the astonished world, Einstein offered a proof. "At

the moment of an eclipse," he said, "just when the moon's disk completely covers the sun and the stars shine brightly in the black sky, a strange thing happens. Look on your star charts. Then gaze at the sky. If the human eye were powerful enough for you to compare the two positions, you would find that the stars in the sky near the eclipsed



Alas for the poet who gazes enraptured at a gleaming star!

sun would seem to have shifted their positions just a wee bit."

To the coasts of West Africa and Brazil, British scientists traveled to prove this, just as Captain James Cook had gone to Tahiti on a similar errand. With the most delicate instruments they photographed the eclipsed sun.

It was with bated breath that the learned world waited for the photographs to be developed. The decision finally came on a memorable day in 1919. "Einstein is right," the scientists announced.

"But what does it mean?" people asked.

"It means," explained Albert Einstein, "that when the starlight passes the sun, it bends as though around a curve. To us it appears that the star itself has shifted."

"It cannot be!" said some dazed ones. "It cannot be that we live in so queer a world!"

That sounds familiar. It is, in fact, exactly what people said when they heard that the earth moves round the sun.

Einstein's theory has withstood every test. Scientists have been forced to change all their views of the universe, as they had to do in the time of Copernicus.

IV

Even if Einstein had never discovered the law of relativity, as his theory is called, he would still be an immortal, for he clarified another great mystery.

Tiny grains of pollen dancing about, and defying the law of gravity! That sight amazed a Scotch botanist, Dr. Robert Brown, as he peered through his microscope at pollen grains zigzagging through the liquid.

"I understand why they do not sink — that's because they are too light. Then, since they are light, why don't they float? What makes them dance about? Are they alive?"

He divided various solids finely — so finely that he could just see the tiny particles in the liquid through his microscope. Still they danced. No matter what kind of particles he used or what fluid he floated them on, the particles darted back and forth.

For nearly a hundred years, scientists were puzzled by these Brownian movements of particles too small to be seen except through powerful microscopes. They offered various explanations.

"Perhaps it is because one part of the liquid is colder than the other."

"Perhaps it is the way light shines on them that makes them dance about."

"Perhaps they are tiny tremblings caused by heavy wagons passing along the street."

But shrewd scientists found errors in all these explanations. Gradually they began to realize that the world is more wonderful than they had ever dreamed — that the molecules, which people talked about, had something to do with the Brownian movements.

"What are molecules? What do they look like?" it was asked.

The answer was clear enough. "Take a drop of water. Divide it in half, then divide this in half, and again in half. After a time the droplet of water will be too small to be seen by the naked eye. Imagine this droplet again divided, and again . . . Soon the most powerful microscope will not help you see the tiny drop of water left. You have reached the end of the droplet. The end is one molecule of water. If you attempt to divide it, it will no longer be water — it will become hydrogen and oxygen."

"How do you know that there are molecules? You can't see them."

"Not yet, but we can see what they do. They are like so many little rubber balls bouncing back and forth. That helps to explain the Brownian movement. When hundreds of molecules of water bombard the little grains of pollen, they cause the grains to zigzag first here, then there. We have not worked it out completely. Wait . . . Perhaps some day some one will explain it all . . . "

The day came, and it was Albert Einstein who explained it all. He found that the little grains of pollen danced to a mathematical law.

Honors have come to this "Newton of the Twentieth Century" from all sides: the Nobel Prize in 1921, hon-

orary degrees from universities, invitations to lecture. When he visited the United States, his lecture halls could not hold all the people who sought admission.

But this wizard, whose theories may revolutionize our thinking as surely as did those of Copernicus and Newton, is not interested in science and mathematics alone. He is besides an excellent musician, performing on the violin and piano so well as to astonish all who hear him. And the same man, who wished to be a teacher to avoid the turmoil of the world and the disgusting struggles which pit man against man selfishly, has served the cause of world peace as a member of the League of Nations committees to bring about the complete outlawing of war.

Not only for his discovery of the theory of relativity and his important discoveries in the realm of atoms and electrons, but also for his longing for peace among men, the name of Albert Einstein is imperishable.

BOOK II

HEROES OF BIOLOGY AND MEDICINE

WILLIAM HARVEY

(1578–1657)

The Beginning of Modern Physiology

I

WHEN William Shakespeare lay in his bed in Stratford-on-Avon, a few days before his eyes shut forever, the historical curtain in another part of England arose on a startling scene.

It is in London, in the theater of the Royal College of Physicians. On the benches, inclined semicircularly one above the other, sits a curious throng — students, surgeons, officials of state, trustees of the college, and private citizens. All eyes are directed to a table in the center of the theater. On this table is stretched the corpse of a criminal, executed the day before. At either end of the table stands a "Master of the Anatomy", scalpel in hand, waiting to expose the structure of the body at the bidding of the chief actor in the scene.

He, the chief actor, is sitting opposite the center of the table. On his head is the cap denoting a doctor. He is a small, dark man with a round face and curly hair. His eyes are brilliantly black and full of spirit.

He holds a little wand with which he alternately gestures in the air and touches here and there the cadaver. By the sheer magnetism of his personality, he is making a powerful impression.

"In half an hour," his words flow with rapid earnest-

ness, "the heart pumps out of its chambers more blood than is contained in the whole body. Whence does the heart get its inexhaustible supply? Where does it all go?"

The crowd stirs uneasily. This Harvey is a disturbing fellow. Why challenge a question that was settled and laid to rest long ago — by the revered Galen, by the great Aristotle?

"What line can you draw with your pencil, my fellow students, that has no end to it? A circle. How can the heart eject all the blood in the body without running dry in a half hour? There can be only one answer: by using the same blood over and over again."

In the assembly excitement runs rampant. The layman opens wide his eyes, the student's pencil glides briskly, the doctors appear to be scandalized as if fearful lest Aristotle and Galen are groaning in their graves.

"The blood circulates through the body." Impossible! Has the fellow no respect for the ancient masters of medicine and for the present beliefs?

"But, Dr. Harvey," some one implores, "Galen says that the blood travels through the body like people moving through the streets of a city." And another adds, "The divine Aristotle teaches that the blood is created from food in the liver which sends it to the heart. From the heart it is distributed by the veins through the body."

"The veins go *toward* the heart," Harvey calmly corrects, "and the arteries carry the blood *away* from that organ."

"Worse and worse! You mean the arteries actually carry blood?"

"Certainly."

"But we understand the arteries carry air or spirit."

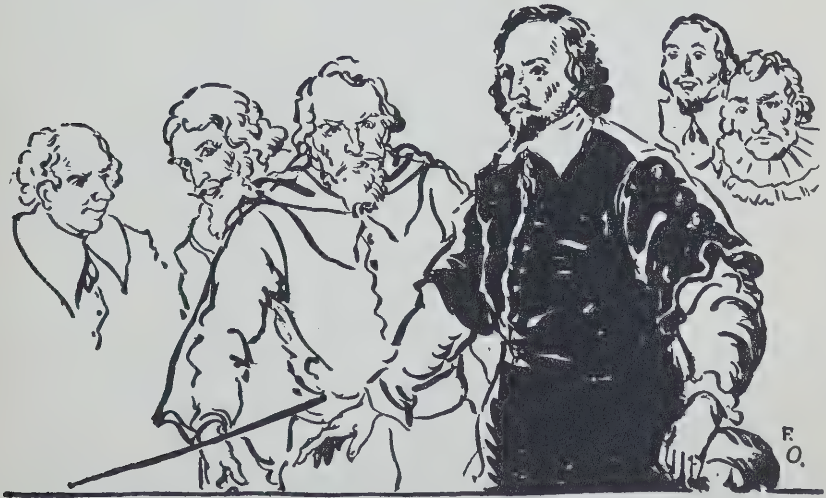
"Look here," says William Harvey impatiently, indicating a chart, "I'll show the process to you; you shall see it with your very eyes. It is not mysterious. The heart

dilates with blood. Then it contracts and squeezes the blood into the arteries. The heart's constant pumping causes the pulse beat which is heard."

He stops and gazes about him to see what effect his words have had. Surely he has proved to them that the blood circulates! They cannot refuse to believe their eyes! But on the faces of his fellow doctors he reads cold scorn and hostility. He is either slightly mad, they think, or a fool.

Well, then, he will debate no more with them. He flings down his wand contemptuously and, turning abruptly on his heel, strides angrily out of the theater.

William Harvey sometimes acted in that way. Not that he was bullheaded; he enjoyed nothing better than a struggle for real convictions. But the unreasonable fear of new ideas enraged him.



The unreasonable fear of new ideas enraged Harvey.

Besides, he had not simply babbled a new idea, like some upstart. He had not announced his theory to the world until he was sure he was right. Many a year had he spent

studying the circulation of the blood, and in over forty different kinds of creatures — fishes, reptiles, birds, snails, crabs. Not until after that prolonged examination had he begun to apply his theory to human blood.

Nevertheless, his discovery of the circulation of the blood met with such opposition from the world's leading anatomists that more than twenty-five years passed before recognition came to him. Meanwhile people believed him crack-brained. Physicians derided him. Harvey, however, was entirely unmoved in his opinion by such abuse. Only a cannon could shock him out of his scholarly position.

And once a cannon did so. It was at a time when the English king, Charles I, was at war with his Scotch subjects. Harvey was personally attending King Charles, and was present with him at the battle of Edgehill on October 23, 1642.

On that occasion, the king, in a moment of calmness which preceded the battle, noticed that his physician was not to be found. Actually, Harvey was behind a bush at the edge of the hill, deeply immersed in a book he had brought along with him. He was not permitted to read long, for the hostilities would not wait, and a bullet from a gun, grazing the foliage near by, forced him regretfully to change his position.

It turned out that he was no mere spectator of the fight. His book pocketed, he gave as good an account of himself as any. In his treatment of the wounded, he then and there proved the correctness of his theory, which gave him a truer understanding of physiology.

One of the soldiers, Adrian Scrope, receiving several wounds, was stripped and left among the dead. His son, who recovered the body, doubtless for burial, encountered Harvey. He, to the amazement of all, brought the man back to life and health. In fact, Adrian Scrope lived to be wounded many more times.

An incident like this inclined people to reflect, "How much Harvey knows about physiology! Maybe the blood does circulate after all."

II

"Maybe!" Such was the doubt the graybeards then cast upon William Harvey.

To-day, if by some miracle it were shown that Harvey had been wrong, every honest doctor would take his sign off his door. All his science is based on trust in Harvey's theory, and without that trust he could not help his patients. The miracle, of course, can never happen. The discovery, which was so full of difficulty for Harvey that he often despaired of success, every doctor to-day has proved again and again. What Harvey had to imagine with deep insight, every medical freshman now can see with his own eyes, thanks to scientific discoveries and inventions since Harvey's day.

When you have sent for the doctor, the first question he asks is, "How is your circulation?" He does not ask the question with words; he takes your pulse, and waits for the answer to be ticked out to him. He may also listen at your chest for an answer.

"Lubb-dup — lubb-dup," he hears.

The doctor understands. The *lubb-dup* is like the turning of a key to a room wherein he may view the working of your bodily machine. The doctor first takes notice of the pump, your heart. He sees a bag with several chambers through which your stream of life is being sucked in and forced out.

The right side is the entrance for the blood. Purple in color, it flows in, bereft of its strength and carrying waste. The entrance way is through a flaplike valve which opens and shuts about seventy times a minute. That is your

pulse rate if you are not sick. Everywhere there are valves, directing a one-way traffic.

"My heart is beating," you say. What you mean is that your valves are tapping and so making your heart knock against your chest.

When the purple blood is halfway through the heart, it does not go straight on. Surrounding the heart is a spongy organ made up of millions of tiny sacs filled with air — your lungs. In between these sacs the blood spreads and trickles, greedily refreshing itself with the oxygen of the air which the lungs have taken in and which turns it rosy. Then, giving up its own waste, which is carbon dioxide, it returns to the heart, ready to carry the fresh nourishment, the oxygen, through the body.

Out into the main artery it flows — one branch to the head and arms, the other through the trunk and legs. All along the way it leaves its helpful oxygen and carries off the waste. It visits every organ. At the intestines it picks up the absorbed food, takes some of that to the liver, and stores the rest under muscles, around other organs, and under the skin. It does a few other important errands, and by this time is purple for lack of oxygen. But no matter; it is on its way back to the heart again.

Your doctor finds that your heart is knocking against your chest oftener than it should.

"You have a rapid pulse," he says. That may mean that some part of you is in trouble, and the heart has to send it more oxygen than usual. It drives billions of red corpuscles through the blood, therefore, to yield the troubled part as much oxygen as it needs. So the doctor has his clue.

In many ways Harvey's discovery helps you to understand yourself. Thanksgiving evening, for instance, after you have had three helpings of turkey and vegetables and pieces of mince and pumpkin pie, you feel a drowsiness

gripping you. You become tired, stupid, and sleepy. Certainly! You have eaten so much that you need more help from the blood than usual for digestion. The blood from the head, therefore, rushes down to help.

Perhaps you are the kind that cannot exercise violently. Too bad! In a fast game of tennis, the body needs perhaps four times as much oxygen as usual. In your case, the heart is not strong enough to pump so rapidly, and you are therefore short of breath.

Harvey has led us on also to further discovery. Recently we have found in the body certain glands that make us what we are — big headed or small headed, tall or short, nervous or stolid. In the throat, for example, there is a gland which pours its secretion into the blood stream. If this thyroid gland is over active, the person is, too. He is jumpy, irritable, and quick. But should the gland not be a busy one, the owner of it is slow, and maybe dull. You ought not then to blame your neighbor for being stupid. The poor fellow may have lazy glands. And it is not amazing that you are so brilliant. You are blessed with active glands.

But the matter of secretion is not as simple as it seems, nor is it fully understood. It is still an exciting mystery. Another William Harvey, perhaps, will clear it up soon.

III

It is curious that although William Harvey was so unworldly that his brother had to take charge of his money in order to prevent him from giving it all away, he was yet hard-headed and sensible.

For instance, in 1634, Edward Robinson, a boy of ten, living in Lancashire, played truant from school. To avoid being punished, he gave as an excuse that he was the victim

of a hair-raising adventure. He said that, as he was passing through a thickly-wooded glade, he saw two greyhounds. A hare appeared at the same time, so he tried to incite the dogs, but neither of them would stir. Angry at the beasts, he took up a switch and was about to punish them, when one of the dogs became transformed into a woman, the other into a little boy. In the woman he recognized a neighbor, a certain Mother Dickenson. She offered him money to sell his soul to the devil, but he refused. A host of other witches soon appeared, and Edward Robinson, carried away by his tale, said he could recognize them if he saw them again.

He was led from church to church to identify these evil spirits, and many good persons were arrested on the popular superstition that witches existed. The case became notorious. Seven of those arrested were condemned, when it occurred to the king to ask the advice of William Harvey. Harvey looked into the affair briefly.

"Witches!" he sniffed contemptuously. "Why cannot people be sensible?"

As a result of his report, four of the seven convicted witches were pardoned. Harvey abhorred ignorance and superstition as most people dislike the dark.

He set himself apart, even when past the prime of life, to better his knowledge. He studied mathematics and the anatomy of birds, frogs and toads with the thoroughness which befitted one who in his youth had studied in Italy, then the center of learning. He had graduated at Padua. Upon his diploma, his teachers wrote, "He has surpassed even the great hopes his examiners held for him."

He wrote a good deal at this time, but except for his famous work, "Treatise On the Circulation", very little has come down to us. Who knows what the world lost because of one of those casualties of war almost as horrible as

the slaughter of living people? "Whilst in attendance on His Majesty the King," Harvey tells, "during our late troubles . . . certain rapacious hands not only stripped my house of all its furniture, but, what is a subject of far greater regret to me, my enemies abstracted from my museum the fruits of many years of toil. Whence it has come to pass that many observations, particularly on the generation of insects, have perished."

"Let gentle minds forgive me," he continues, "if recalling the irreparable injuries I have suffered, I here give vent to a sigh." Contemplative and gentle, with charm and generosity, no wonder this great man was loved far and wide. Amidst the genuine grief of all he went to his grave at the age of seventy, in the summer of 1657.

His discovery of the function of the heart and of the circulation of the blood was the greatest event in medical history up to that time, for it made possible the science of physiology.

ANTON VAN LEEUWENHOEK
(1632–1723)

Discoverer of the Invisible World

I

If you had asked an inhabitant of Delft, Holland, what sort of man was Anton van Leeuwenhoek, you would have been told he was queer; a strange, odd man.

"Why?" you might have continued.

"Well, he is a janitor by occupation. But his strangeness is not due to that. It is what he is constantly doing in his spare time. First of all he grinds lenses in an odd way. His famous glasses make a thing look two hundred seventy times bigger than it really is. Many of them he has. He will not sell them, nor will he give them away. He guards them jealously and asks you to be careful when he lets you look through them."

"There is nothing funny in that," you say.

"Ah, no. But this is funny: all day long — his duties as janitor are light — he goes around with his microscope. He examines everything. If you come to visit him, he may greet you with: 'Hold still for a minute. I'd like to look into your ear . . . Let me peer between your teeth.' He peers at everything — the skin of his hand, the head of a fly, ant eggs."

"Well, does he find anything when he peers?"

"That is the amazing thing. He finds there are many more inhabitants in the world than we can see or dream of. Only yesterday he told me I had a nice garden growing

between my teeth. I thought, of course, he was joking, until he scraped my teeth and put the scraping under his glass when, Heaven help me, I saw things move about, living things! And in my barrel of drinking water he found a whole colony of animals alive, which appeared under his glass. To think I have been drinking from that barrel all these years! Where do these animals come from? How? . . . Yes, Leeuwenhoek himself is queer enough, but the things he shows us are queerer still."

It was all true. Other noble souls might discover awful planets wending their majestic way in the heavens, but this fellow was inspired by — fleas, lice, worms, and creatures ten thousand times smaller, which he tried with his lenses to make look as big as elephants.

No microscope was powerful enough for him. He was all the time making better ones. And the number he made was enormous! Two hundred forty-seven complete microscopes, not counting one hundred seventy-two magnifying lenses.

"Why not?" he defended proudly. "If Aristotle had had my glasses, he would not have made the blunders he did." For Aristotle had said that plant lice arise from dew, and fleas spring from mud. He called this spontaneous generation.

This was a common belief, and a learned man of that day had even given out a recipe for making mice. "Put some dirty linen in a basket," he wrote, "together with a few grains of wheat and a piece of cheese. In a few days, a mouse, two, three, and many more, will come of it all."

"This is not true," maintained Leeuwenhoek. "I have seen creatures hatched from minute eggs brought by winged insects or by the dust of the air. Every living thing, no matter how small, has a parent. Spontaneous generation is a fable; nothing else. Not only are fleas born in the usual way, but sometimes they are attacked and fed

upon by a mite — in other words, even a flea may have its own fleas to worry it."

"... a flea
Has smaller fleas that on him prey;
And these have smaller still to bite 'em;
And so proceed ad infinitum."

II

With his magic lenses Leeuwenhoek discovered the world of one-celled beings, more astounding than any dream world, more important than Columbus'; billions upon billions of living animals and plants around us, upon us, within us.

He looked at rain water. What could he hope to discover there? Yet soon fantastic shapes could be made out. Excitedly he watched these animalcules, creatures unlike those we see with the naked eye, swimming in water. Like Columbus, he had discovered a world — the world of first life — Protozoa.

"I've discovered," he wrote elatedly to the Royal Society in England, "living creatures in rain water which had stood but a few days in a new earthen pot . . . Those little animals appeared to me ten thousand times smaller than water fleas, which may be perceived in the water with the naked eye . . . When they moved, they put forth two little horns. The place between these two horns was flat, though the rest of the body was roundish, sharpening a little towards the end, where they had a tail, near four times the length of the whole body, of the thickness of a spider web . . ."

Here is another kind, "moving about very nimbly, furnished with incredibly thin feet." Sometimes "they stop, they stand still as 'twere upon a point, and then turn

themselves round with that swiftness, as we see a top turn round, the circumference they make being no bigger than that of a fine grain of sand."

The Society was utterly bewildered. Their imagination had roamed in the realms of immense things: fabulous

He had discovered the world of first life — Protozoa.

unicorns the size of elephants, and fiery hippogriffs, and birds like Sindbad's roc whose egg was as large as a hill. But here was a real animal whose whole body was nothing but one single, solitary cell. And that is next to nothing at all. Why, the tip of the finger has thousands of cells!

The more they thought about it, the more amazing it seemed. How could any one imagine an animal — living, breathing, moving from place to place, eating, preying greedily on other animals — and itself the size of one cell! Why, a flea must appear to be a whole world to it.

A teaspoonful of mud must have a greater population than the human population of America.

The world would have liked to doubt all this. It was so uncomfortable to feel that upon you, inside you, on your food, you were entertaining parties of unbidden guests. It was more uncomfortable to feel that you could do nothing about it. But how could any one doubt? Leeuwenhoek was inexorable.

"Take a little water from a rain spout and look at it through a microscope," he insisted.

"What about the manners of these protozoan creatures?" people asked innocently. They remembered how an old English writer had described mice as "vulgar little animals, evil, apt to steal, and deceitful by nature." The flea, another had said, was a vicious little worm. "It desireth blood, and spareth not kings." And parrots, an old Roman had written, perish of grief when they cannot pronounce certain hard words.

Pleased with such unscientific nonsense, every one wanted to know the habits of these mites under Leeuwenhoek's glass.

In good time they learned about the terrible struggle for life among the Protozoa. Their one cell is made of something like jelly. Yet they are not alike, Leeuwenhoek saw. They differ as much as a dog and an elephant. But they all, even as kings, must eat.

"But what is their shape? And how can they eat, and breathe, and get about — all with one cell?"

That *is* strange. But just watch the microscope! One of the most ordinary of Protozoa is called the amoeba. He cannot be said to have any sort of shape, he changes so. Now watch him. This living speck of jelly somehow flows and rolls along, in search of dinner. It happens that another but smaller one-celled being crosses the path of our hero, the amoeba. A tense moment!

Suddenly the amoeba, resorting to strategy, surrounds his enemy. That is the advantage of being shapeless.

Poor captive protozoön! No quarter is shown him. He

finds himself surprisingly inside the amoeba. Any convenient part of the amoeba, you see, is his mouth, and on the inside he is all stomach. So, even as a king, he dines. But, unlike a king, when he grows too big, he divides in half, and there are two amoebae, where once there was but one.

Some Protozoa prefer the sea. When that is the case, as creatures of the deep they are usually fitted with shells, just like the more masterful snail or turtle. If in life one-celled things seem insignificant, in death the sea Protozoa serve nobly. As they die, the shells sink, pile up, turn to rock, and in aeons of time the pile rises up out of the sea . . . It was the Protozoa that built the famous chalk cliffs of England. One might almost say that England expects every protozoön to do his duty.

Leeuwenhoek was puzzled by one matter. Whence came the amoebae in the rain water? "Surely, not from the sky," he thought. To find out, he took a big porcelain dish and, washing it clean, he carried it out into the rain and put it on top of a big box. "No mud must splash into the dish," he thought, "for mud contains living beings." He studied the rain water. It did not contain a single creature. Therefore, they do not come from the sky.

But he kept that water. Hour after hour, day after day, he peered at it. Then one day, he saw animalcules begin to appear along with bits of dust.

But he was cautious. He turned his glass on all conditions of water, water from wells and from the canals of Delft. In all gutters he found the wee beasts. "The dust carries them there," he said.

"Every living thing," he repeated, "has a parent."

III

One day the Royal Society received another letter from Leeuwenhoek. "Although I am now fifty years old," they

read, "I have well-preserved teeth, because it is my custom every morning to rub my teeth very hard with salt, and after cleaning my large teeth with a quill, to rub them vigorously with a cloth . . . Nevertheless, when I view them with a magnifying glass, I find growing between them a little white matter as thick as wetted flour. I thought that in this substance lurked living creatures.

"I therefore took some of this flour and mixed it with pure rain water wherein were no animals; and to my great surprise saw many small living creatures moving about. The biggest sort darted through the water, as a pike-fish does. Some spun like a top. Others looked like bent sticks or threads . . . but some were small and swift, like a swarm of flies or gnats, flying and turning among one another in a small space. Of this sort, I believe there might be many thousands in a quantity of water no bigger than a grain of sand." As living things, he saw a vast difference between these creatures and those he had formerly seen in the standing rain water. Before he had discovered Protozoa; now he discovered bacteria, the one-celled plants.

He began to examine everybody he could enlist. He studied two women, a child of eight years, the spittle of an old man. He gazed upon a great many tiny living creatures, swimming more nimbly than any he had ever seen.

As the years went by, he continued his careful observations. All Europe began now to recognize him. When Peter the Great of Russia visited Holland, he came to pay his respects to this janitor of the City Hall of Delft. The Queen of England journeyed especially to Delft to look at the wonders to be seen through his lenses. Success, however, did not spoil him. He worked all the harder for it.

"Captain," he begged a fisherman, "promise you will some day bring me the eye of a whale."

"Hans," he would instruct his servant, "this afternoon

you will catch me a few fleas. But take care not to hold them too tightly. You may hurt them."

The world was so full of wonderful things! He could think of no greater joy than to put a piece of the bark of a tree under his lens — and then what a strange thing he saw! No longer was it a mere splinter of brown wood. It became a marvellous network of fibers, never before so seen. And if he were lucky, he might find hidden in the bark the minute eggs of some insect.

A dead cat was full of miracles for him. Its eyes, its flesh, its nerves, all revealed new wonders under his magic glass.

"But what use are these creatures?" he was asked. "Some beasts are for mirth, like marmosets and popinjays. Others are for sorrow, like flies. But your one-celled mites . . . ?"

To this Leeuwenhoek could not reply. With all his peering he never realized what his discoveries were later to mean. It was left for Louis Pasteur, two hundred years later, to show that these mites cause fevers, lockjaw, tuberculosis, diphtheria. With these enemy bacteria our heroes of medicine do battle. Not that all bacteria are enemies of mankind. Our agriculture could not go on but for friendly bacteria; nor could we make cheese or buttermilk. And our digestion, when it is good, depends on the helpful sort of bacteria.

Yet it is true — and Leeuwenhoek would have been astounded to know it — that his Protozoa toppled Rome from her greatness. For ages it was known that the swampy places near Rome were subject to attacks of malaria. In Rome itself thousands fell victim to the fever. To get rid of this dread disease seemed beyond the hopes of man. "What causes malaria?" people asked. "Bad air," the doctors ventured. But not until long after was it real-

ized that malaria is caused by a kind of protozoön that lives on the blood of man.

When Leeuwenhoek learned about William Harvey and his great discovery of blood circulation, he turned his lens on the blood stream. Harvey had never been able to see the blood flowing through the capillaries or its pouring from the arteries to the veins. He just reasoned it out. But Leeuwenhoek was unsatisfied till he had seen it.

To bring before his eyes the blood circulation, he experimented with all kinds and parts of animals; the comb of a young cock, the tail of an eel, the ears of white rabbits, the wings of a bat, the web of a frog's foot. One day he examined the transparent tail of a tadpole. Here was a sight more delightful than any he had ever beheld. For his eyes traced the red corpuscles floating through wide arteries, which taper so narrowly that the corpuscles must squeeze their way through the capillaries into the veins.

When he was ninety-one years old, Leeuwenhoek sent for his friend Hoogvliet. "Hoogvliet, my friend," he said, "be so good as to have those two letters on the table translated into Latin. Send them to London to the Royal Society . . . "

"I send you, learned sirs," Hoogvliet wrote, "this last gift of my dying friend, hoping that his final word will be agreeable to you."

Agreeable! Leeuwenhoek had opened up a world full of mystery to our startled sight, a world of life and death which was to compel the attention of our greatest scientists for all time.

EDWARD JENNER

(1749–1823)

A Modern Theseus

I

At about the time of the American Revolution, a group of distinguished Englishmen were enjoying the holiday season at Bath. They met one evening to dine and make merry, when a discussion arose.

"You are wrong," said one, "the hottest part of a candle flame is the center."

"Oh, no," said another, "it seems to me that the hottest part is near the apex."

So it went, back and forth, without reaching any conclusion, when suddenly a young man stepped forward and seized a lighted candle.

"Gentlemen," he said, "be silent and look." He placed the candle before him, and before any one could stop him, he had thrust his finger into the center of the flame.

"It's a trifle warm," he smiled, "but you see it . . ." At this point he was compelled to withdraw his finger.

"Now for the apex." He advanced his finger cautiously, but no sooner had he touched the bluish part of the flame than he exclaimed in pain and withdrew his finger.

The question was settled.

"Who is that young man?" whispered a certain diplomat to Dr. Beddoes, who was later to be the employer of Humphry Davy.

"That is Dr. Edward Jenner."

"What an able scientist!" said the diplomat fervidly. "I am so impressed with him that I shall obtain for him a post of high authority in the East Indies. The nation ought to recognize its men of talent."

Beddoes shook his head. "No use trying that," he returned. "You can no more get him out of his small country town where he studies the birds and flowers and tends the sick, than you can induce a fish to leave the water."

A clapping of hands interrupted this conversation. They turned and saw Jenner standing in the middle of the room with a paper in his hand. "They have prevailed on him to read his poetry," said Beddoes. "I think he is one of the best of poets. Listen."

"This is on the death of a miser," began Jenner slowly. "It isn't very good . . ."

"Never mind what you think," said one of the number. "Let us judge."

"Well then:

Tom at last has laid by his old niggardly forms,
And now gives good dinners; to whom, pray? — the worms."

Shouts and laughter rang out, "Bravo! More! More!"

"If you like," said the shy poet . . .

II

The Minotaur was a fabled monster of ancient times which regularly ate seven youths and seven maidens. The hero Theseus finally slew it.

But there was a monster far more terrible than the Minotaur. Invisible and fatal, it stalked the earth far and wide, and every day took its toll of men, women, and children. Men called it the smallpox — and no Theseus had been born to slay it.

The pall of constant fear was upon every mother. At any moment, her husband, her little tot, might be seized with the dread disease, the victim wracked with fever and chills, stupefied, emitting an offensive discharge from mouth and nostrils. There might be some hope welling in the poor woman's breast, until she saw the horrible pustules break out over her dear one's body. They were the final mark of the specter upon its victim. Even if he should recover — and the chance was slight — he would bear witness of the disease to his grave, being either disfigured with pock marks, lame, or blind.

The constant anxiety was hard to bear. Men prayed that the disease might come to them early. Then they would be over the ordeal, and if they lived, they would never have to face it again.

Where did the monster come from? No one knew, but it seemed everlasting and everywhere. About twenty-five hundred years ago, it fell upon Rome and destroyed so many that there were not enough wagons in the city on which to bear the dead, and the remaining bodies had to be thrown into the river Tiber. In Egypt, in China, and in India it was known from earliest times. When it appeared in Ceylon, whole villages were wiped out. In Russia smallpox has been known to cut down two million people in a single year; and every seventh child fell a victim to this disease.

Every twenty-five years, about one million, five hundred thousand human beings were slaughtered by it, and of those recovering, three-fourths were blind.

Into the house of Dr. Jenner, one day, stepped a young milkmaid. She had come to seek advice from the kind doctor, who soothed her, saying, "You will be fully recovered in a few days, I think. Now if you'd had the smallpox . . . " he finished smiling.

"I cannot have that disease," said the young woman quickly. "I have had cowpox."

Jenner was startled. Why could she not? What was the connection between cowpox and smallpox, he asked himself. He visited all the villages around and found to be true what the milkmaid had said. If any one caught cowpox — which was not at all serious to human beings — he never had smallpox. Now Jenner knew that if any one had had smallpox, he could never get that again. But what had cowpox to do with smallpox? Can it be, he reasoned, that cowpox and smallpox are one and the same — that it takes one form in cows and another in human beings?

He spent the following days in the stables and pastures and observed carefully. On a farm where all the live stock were hale and hearty, his attention was arrested one day by a horse which had become infected with a hoof disease known as "grease." Nothing else happened for a few days. Then suddenly the pox broke out among the cows and swine. In a short while a milkmaid had cowpox on her hands. At the same time, the little village was struck by an epidemic of smallpox.

"There," said Jenner, pointing to the horse's diseased heels, "there is the source of this smallpox. Evidently pox leaves no animal untouched, and thus it appears in horses, cows and swine. That person is lucky who catches the disease from these animals, for then he has it in the very mildest form and also is rendered safe against the terrible human form of pox."

The doctors of London were not impressed. "A little country doctor!" they said and waved him aside.

But the "little country doctor", who had discovered the cause of a well-known heart trouble, who had studied and described accurately the habits of the cuckoo and the hedgehog, meant to put his newest discovery to the test.

He could not ask other people to risk their lives in the experiment, and he himself was already proof against smallpox. Whose life could he risk? He talked to his wife, the mother of his boy . . . It did not take them long to decide, these two who thought of all humankind paying its yearly tribute to the Minotaur, of other fathers and mothers who cringed in terror at the sight of the deadly eruption on the bodies of their little ones . . . It did not take these parents long to decide. Their little Edward's arm was bared for the sacrifice, for the first step in the experiment.

Matter from swinepox pustules was injected into his arm. The mild form of the disease took hold on the lad, and he suffered hardly any sickness at all. This was what Jenner expected.

And then the great ordeal came. From the sores of a child, who was having smallpox in the regular, deadly way, Jenner took some matter. Into the arm of little Edward he injected this. The father prayed anxiously. Days passed, and at last it was clear that the child was spared. The swinepox poison, or vaccine as Jenner called it, had outwitted the smallpox.

It was time to rejoice. But Jenner, the scientist, was cautious. Either cowpox vaccine or swinepox vaccine would prevent smallpox. But how much vaccine should be used? What was the right time to use it and how?

For seven years he experimented and studied the problem. Then in 1796, on the fourteenth of May — in Berlin they make it a holiday and call it Jenner's Day — he vaccinated James Phipps, a healthy boy eight years old. Following the vaccination, he innoculated him with smallpox. Then it was indeed time for the world to rejoice; James Phipps remained as healthy as ever.

Theseus had slain the Minotaur.

The little country doctor's name was on the tongue of

all intelligent people. The end of one of the deadliest of all diseases was in sight.

III

Few men in the history of the world have saved as many lives as Edward Jenner. Vaccination, his discovery, has been one of the greatest boons to mankind. Emperors for their subjects and parents for their children blessed him. In Russia the first child to be vaccinated was christened "Vaccinov", and pensioned for life. The Emperor of Russia, in gratitude, sent the little country doctor a gift. Even the American Indians sent him a wampum belt, to say that he had saved them also.

Thomas Jefferson, then president of the United States, wrote to him, saying, "You have erased from the calendar of human affliction one of its greatest . . . Mankind can never forget that you have lived . . ." And mankind never will.

A Jenner Society was formed in London, and Jenner was implored to come to London. "Ten thousand pounds every year we guarantee you," they said. But in vain. He refused.

He was far from rich, but he cared nothing for fame, honor, or money. More dear to him than everything else was his little country house where he could spend the rest of his life studying nature and tending the poor and sick. He had a modest income, and refused to take money for vaccinating. On some days, outside his door, more than three hundred people would gather, each waiting his turn to be vaccinated.

"Yes, be vaccinated," the kindly country doctor urged. "Instead of waiting for the disease to attack us and then to worry about its cause and cure, let us prevent the disease from ever striking us."

A brilliant idea. When Jenner wrote his book on the cause of smallpox, the London doctors were indifferent to it, yet as time went on, they reflected seriously, "Vaccine! That is how Jenner has conquered a plague which used to kill or disable one out of every four people. Now why can we not use a similar method and stamp out other diseases?"

Few men have saved as many lives as Edward Jenner.

Jenner had shown the way. Since his time doctors have tried to apply his theory to many diseases.

"What do we suffer from? Typhoid, diphtheria . . . We must find a vaccine — our best weapon — against these enemies."

The vaccine, doctors saw, somehow strengthened the blood and cells of the body, so that they were more powerful than the disease. The way was clear then. The laboratories of scientists became factories for vaccine.

And one disease after another is being conquered by Jenner's great discovery of vaccine treatment. Typhoid, for instance, with its stealthy approach through fever and

chills, had many a time wiped out valuable lives and high hopes; but now, merely a prick of the vaccine needle, a burning pain and a hot sensation for only a few moments — and you can laugh at the dangerous typhoid, where before you might have succumbed to it.

No, it is no longer a struggle between gaunt disease and a puny individual. We do not have to suffer in uncertainty until a Black Death empties towns of their population and leaves ships wandering on the seas with dead men for crews. "Let us prevent disease. An ounce of prevention is better than a pound of cure," became the slogan of scientists. Instead of only a vaccine against smallpox, we now have special vaccines against a dozen diseases. And who knows but in the future, with heroes like Jenner fighting for us, we may not even have to suffer a common cold?

The entire community has joined in the fight against possible infection. "We will guard against the enemy, where he usually attacks. We will take no chances. Diseases are spread by infected milk and infected food, among other things." That was certain. "Therefore we must protect ourselves by Pure Food Laws."

But should one of us, in spite of everything, fall victim to a contagious, a "catching", disease, are we helpless? Must more of us have the disease, catch it from the first victim? Not at all. We simply fence in the disease so it cannot spread. We quarantine the patient.

In Jenner's day that was hard to do. We know, in fact, that the terrible overcrowding in cities in those days was one reason for epidemics. Then there were slums, long alleys so narrow that they were barely passageways. What chance was there here for sunshine and fresh air, or for clean conditions — for anything but vermin and rats?

To-day we are fighting against dirt and gloom. By "a

healthful life and healthful surroundings" we are preventing epidemics.

But the wisdom which leads us to this manner of living, began the day the little country doctor discovered his vaccine — Edward Jenner, the sound of whose name was like a blessing.

One day in the palace of Napoleon, the Empress Josephine was reading aloud a petition, lately arrived from England. Napoleon was pacing the floor.

"No, no," he interrupted. "Release those English prisoners? Never!"

Josephine kept on to the end.

"Never mind finishing," said Napoleon angrily. "Why should France set free her enemy's soldiers? Why . . ." he stopped. His ear had caught something. "Who signed the petition?" he asked in softer tones.

"Edward Jenner."

"Ah," sighed Napoleon, "we can refuse nothing to that name."

LOUIS PASTEUR

(1822-1895)

"Look for the Germ . . ."

I

"SOME little bug will get you some day," sang a charming little ditty of recent years. Earlier, in the day of the young Pasteur, nobody believed that, or even dreamed of it.

It was all discovered because of bad beer.

"Why has our beer become so bitter?" the puzzled brewers asked the young professor of chemistry in Paris.

"And the wine has turned to vinegar," chimed in the vintners sorrowfully. "Help us," they pleaded.

Pasteur was always eager to help. He had long before dedicated his mind to the healing of human suffering, however he could. "Time spent in any other way is a waste," he thought. "There is no amusement like work." With a zest, therefore, that only the promise of great work could inspire, he began to peer down through his microscope on some specimens of the bad beer and wine.

The liquid seemed alive. Men had said that milk or wine turned sour and beer bitter, that these liquids fermented from their own natures. Here Pasteur saw living creatures, tiny things alive and working busily, models of industry, but — they spoiled the drink.

Pasteur rushed to the brewers. "Look," he cried, "here are the rascals that are ruining your product. Rid your vats of them and your business is saved."

But how could these creatures, invisible to the naked eye, get into a vat? Leeuwenhoek had proved that there was only one way — through the air. Pasteur, therefore,

sterilized the air in a room in order to kill off any microbes floating there. He then heated a sample of beer, and time showed that under these conditions the liquid kept sweet and good.

To-day, before milk is bottled, we do with it as Pasteur did with the beer: we heat it high enough to kill any germs that may have found their way into the liquid. We call this "Pasteurization." Many communities allow only Pasteurized milk to be sold, for in no other way can people be protected against diseases which may be spread by infected milk.

"You see," said Pasteur, "the dust, which the air carries, is laden with germs and microbes. The dust, falling into your liquid, deposits these bacteria and they multiply fast. Keep your vats free of any dust and your liquid will never spoil."

As he said this, a remarkable idea entered his head — so remarkable that it made Pasteur tremble with excitement. History still glows with the importance of that moment and the world will celebrate it in the name of thousands upon thousands of people who owe their lives to it.

"If microbes or germs cause beverages to go bad and food to rot," thought our genius, "what causes an organ in the human body to waste away and rot and the sufferer to die of disease? Each case must be governed by the same principle."

"Some little bug will get you some day," he announced in scientific words, "and you must look for the germ and lay it low before it conquers you."

II

A long, loud laugh burst from the doctors; and then came resentment. "Just because he made an important discovery in chemistry — something that has to do with

crystals — he has grown too confident," they grumbled. "He thinks he is bound to make another discovery in medicine. What right has a chemist in our midst with his crazy theories?"

"He is probably mad," they were informed, soothingly.

Pasteur himself was in a fever. "Wait," he warned.

His chance came. From the south of France, from Alais, Cévenol, and neighboring districts, a cry of pain arose. The countryside was in a state of starvation. For twenty years things there had been going from bad to worse. The inhabitants were being robbed of their living by a mysterious disease which was destroying the silkworm, the sole source of their livelihood. Italy, Spain, Greece, Turkey, China were also suffering. The misery was terrible. The thousands of people in the silk industry were faint from hunger. Paris must help; somebody must do something. To Pasteur the appeal was borne.

"If I could only help!" he said despairingly. "But I have never even seen a silkworm."

Where none had succeeded, no failure could increase the discouragement. He put his mind to the task as he journeyed south.

It was a time of bitter sorrow for himself. In June of that year, 1865, his father died; in September, his child Camille; the following spring his child Cécile; and shortly after his own body snapped from the strain and trouble. He almost died. But not before he had triumphantly shown that microbes were doing the harm. Then he taught the silkworm growers how to destroy the microbes.

The people of the Cevennes Mountains were hushed in a sort of worship of Pasteur. He had wiped out their scourge and had saved them from starvation. He gave France, in silk alone, more than her gigantic war debt to Germany in 1870; he made it possible to save more lives than Napoleon had slain.

Could Pasteur's theory of germs as the cause of disease still be doubted? Partly from jealousy, partly from sheer incredulity, the world would not take him seriously. A germ, even if it does exist, is such a tiny thing! What harm lies in it?

"Every disease is caused by a germ," he repeated.

Just then, an epidemic of chicken cholera broke out in the poultry districts of France. At sunrise every barnyard told its mournful tale. Here a hen was found sitting on her nest, dead. There a superb cock, which yesterday crowed proudly, lay in the dust, his beak closed, his eye dim, his crest fallen — in the clutch of cholera.

The loss to France was enormous. Said Pasteur, "I shall look for the germ, the chicken-cholera germ, discover it, study the fellow, and find out its weakness."

In the blood of a diseased fowl, he saw microbes. He knew that a drop of this blood injected into a healthy fowl would cause chicken cholera. This sickly blood he put into a container, and kept it there. "Let this culture stand," he said to his assistants. "Some day I shall inoculate a few chickens with this cholera culture."

After several weeks, he returned to his study of chicken cholera. One evening, in order to observe the effects of the disease, he inoculated some fowl with a little of the culture.

The next morning he came down to his laboratory. To his amazement, instead of dead chickens, he found the fowl well and lively. "The culture must be old and weak," he thought. "I must get some fresh diseased blood."

In a few days he had the fresh culture and new chickens also. He infected the whole flock, old and new. A strange thing happened: only the new chickens died.

At first Pasteur was mystified. Then inspiration came to him. The old chickens had once before been injected with a weak culture. That was why they were able to withstand the new deadly culture. "It must be that, if you re-

cover from a disease, you cannot have that same disease again. You are immune." He remembered the vaccine of Jenner who, to protect a man from smallpox, gave the man smallpox, but in the very mild form of cowpox.

"So," Pasteur exclaimed, "we can cure our diseases. Find the germ, and turn it into a vaccine."

The whole French Academy pitied him for saying this. "Poor Pasteur, he must be losing his wits." But Pasteur was too elated to mind.

He went to Chartres to study a disease of cattle which was exterminating half the livestock of France. A sheep would be seen lagging behind the flock, his limbs shaking. A spurt of thick blood would rush through his mouth, a convulsion seize him, and in a few hours anthrax had claimed another victim.

Some of Pasteur's enemies, who had laughed at his idea of vaccines, thought of a plan to trap him. They challenged him to make a vaccine that could prevent anthrax. They offered fifty sheep for the trial. Pasteur accepted the challenge. On a farm near Chartres, in the spring of 1881, the test came. From far and near the world looked upon the scene. It sent its journalists, doctors, and scientists to the spot. As to a sporting event they all came, most of them expecting the champion to fall. Briskly buzzing about the farm, they cast slurs of ridicule on the fighter who had challenged almighty death itself.

The fifty sheep were divided into two groups of twenty-five each. One group was inoculated with the vaccine. The other group was untouched.

Then came the great test, the test which was to decide whether Pasteur was to become immortal or not. The deadly microbes of anthrax were injected into all fifty sheep.

And the result? Pasteur became immortal. The twenty-five sheep, which had the protection of the vaccine, kept

browsing and swishing flies in the best of health, while the unprotected twenty-five succumbed pitiably.

There was no longer any doubt. From that day on Pasteur had not a single enemy. The world was awed by his genius, and a cry of gratitude rang out for the man who had shown the way to save humanity from disease.

Yet he was modest. For instance, he accepted an invitation to attend the International Medical Congress in London. When he arrived at the hall, he was recognized by a steward and asked to mount the platform. As he walked down the aisle, a thunder of applause burst from the audience of scientists.

"It is no doubt the Prince of Wales arriving," said Pasteur as they reached the platform. Turning to his son, who was with him, he added regretfully, "I ought to have come sooner."

"No, it is you whom they are all cheering," the President of the Congress said with a smile.

III

In times gone by hardly any misfortune struck such fear in man as did the bite of a mad dog. The victim, with his intense desire for water, his choking spasms, and his great suffering just before death, so terrified every one around him that often he was left alone to his dreaded fate. Many fantastic tales were told of those bitten by a mad dog. "They bark like dogs," it was said, "and go on all fours."

The cures suggested were even stranger. In olden times, for instance, a famous doctor wrote, "The only remedy is to throw the patient unexpectedly into a pond. If he cannot swim, let him sink, in order that he may drink the water; and when he rises again, again push him below the surface of the water, so that, even if he is unwilling, he will be satiated with water. For thus at the same time

the thirst and the dread of water are removed. But if the water cure enfeebles the patient too much, let him be taken immediately from the water and put in hot oil."

For centuries various remedies were tried. One doctor seriously thought that the wound made by a mad dog should be enlarged, packed with gunpowder, and exploded. If any unfortunate were foolish enough to follow such advice, his friends soon found him cured not only of rabies, but of all other ailments forever.

To Pasteur, armed with his wonder-working vaccines, rabies, or hydrophobia, was a challenge. He made a vaccine against it. But would the vaccine work?

One day his chance came to find out. In a room in Paris lay a lad of nine, who had been bitten fourteen times by a mad dog. By his bedside his mother stood, wringing her hands desperately, knowing well the fate which followed a mad dog's bite. With her wounded son, she had come to Paris from a far province, having nothing but blind hope in a name. "Pasteur," she repeatedly implored.

In another room two famous doctors were urging Pasteur to act.

"Professor," one said, "the boy is as good as dead. The dread rabies will kill him any day now, as surely as it has killed thousands before him. At any moment the ardent thirst, the spasms, the furious rage, and paralysis may seize the boy."

"There is nothing to be lost by trying your antirabic vaccine," urged the other, "and everything to be gained."

Pasteur was pacing the room, agitated.

"Dare I?" he groaned. "I have never tried it on a human being. It works on animals, but on a child . . . I dare not — I dare not. If my treatment fails and little Joseph dies," his voice trembled, "I shall feel responsible."

"Nevertheless, we as doctors can do nothing. You might save the child."

That convinced Pasteur. It would break his heart if he failed. Nobody had ever succeeded in curing rabies, but he must risk it. Tenderly he dried Joseph's tears. The inoculation was given.

In two weeks' time the boy would die or recover. During two weeks Pasteur hardly slept or ate. He was on the verge of breaking down, when the lad began to show signs of improvement. Pasteur was overcome with joy. Not only did the lad recover, but he grew up to give his services to the Pasteur Institute.

From all the grateful world over — for a long period elapses between the bite and the onset of the disease — came cases of rabies to Paris. Four little Americans came,

Four little Americans came.

sent by charity. After the first inoculation, which took but a few seconds, the youngest of these, a boy of only five, said wonderingly, "Is this all we have come such a long journey for?" Those few seconds saved their lives! The kind gentleman who had bent over them with a sweet smile had made it possible. Rabies had given up its terror.

There is no civilized country in the world which has not paid its tribute to this great man, Louis Pasteur. His name has been given to hospitals, towns, and streets, and his birthday is celebrated throughout all Europe.

When the school children in France were asked to name the greatest Frenchmen, many of the adults thought they would choose Napoleon, the man of blood and glory. The children knew better. They could not put the man whose victories brought death and misery to countless families on a level with the man of peace, the life-saver, the joy-bringer. Then the French people, learning from their children, engraved on one of their country's postage stamps the portrait of Louis Pasteur.

There are two ways of life open, Pasteur taught, one the way of blood and death, the way of the battlefield; the other, the way of peace, of health and sunshine. Which of these ways will you choose? Which?

ROBERT KOCH

(1843-1910)

Father of Bacteriology

I

"Can it be?" Dr. Robert Koch wondered. "Can these strange rods and threads really be so deadly?"

His eye was glued fast to the microscope — a pastime at which he had often been found, ever since he was seventeen, when his father had presented him with the microscope. But this time he was especially absorbed. He was gazing down on a drop of the blackish blood of a dead cow, recently killed by that terrible curse, anthrax. Louis Pasteur had not yet begun his brilliant campaign against this disease, but the farmers were already crying out that they would be ruined unless this malady was stamped out. It was small consolation to them that the great Pasteur had boldly declared, "Every disease is caused by a germ."

"To begin with, the declaration, without proof to back it up, is ridiculous. Show the germ! Let us look him in the eye! Let us see him at his murdering work of blackening the blood, choking the blood vessels, and eating up the tissues. Otherwise, why waste thought on this tiniest of living things?" That was the people's attitude.

And the slow, painstaking country doctor, Robert Koch, was in sympathy with such an attitude. "This fellow Pasteur, genius though he be, is far too reckless and impulsive. If anthrax, for instance, is caused by a germ, he ought to show us . . ."

It occurred to him that he might find out for himself. Anthrax in his farm district of Wollstein, Germany, was under his very window. He knew the sad truth, that the very cow that had tolled her bell as she passed his study only yesterday, would doubtless be dead now. The mournful farmer would tell how she had suddenly refused to eat; how her head had drooped and her splendid hulk had sagged; how, before he had realized her trouble, she had died. Then, he knew, other cattle in the same field would die, perhaps all of them. What mysterious power was at work?

"If Pasteur is right," reasoned Koch, "then I ought to see microbes in the blood of this dead cow. But are these rods and threads, these microbes, alive?" He saw them floating in the globule of blood, some long and wavy like threads, others short and straight like rods. "Now here's a drop of healthy cow's blood. There are none of these rods and threads in it. Does that prove that these rods and threads are the anthrax germs?"

Not quite; not for the cautious Koch. He must see the microbes at work.

He selected two mice. One he left as it was. In the tail of the other he made a tiny cut. He dipped a sliver of sterilized wood into the drop of diseased black blood and then touched it to the cut. The mice were put in separate cages.

"Now we shall see."

The night was restless for the doctor. Too much depended on this experiment for him to sleep peacefully. In the morning he ran eagerly to visit the mice. One was dead — the one with the cut in its tail. Its blackish blood swarmed with millions of those familiar rods and threads. Under Koch's very eye the microbes multiplied. A rod would divide in two. The two halves would grow. Then they would each divide again, and keep on in this manner

until they seemed likely to outdo even the multiplication table.

"How can I study these rods?" he asked. "It's difficult enough because they are so tiny — twenty-five thousand to the inch; but if only they didn't move! I must keep them fixed somehow, if I am to learn anything at all about anthrax."

For days he wore a worried look. The country folk were sure their doctor was wasting his time looking for tiny bugs too small to be seen by the eye — and yet he claimed that these bugs killed the strongest ox. "Our doctor has a vivid imagination," was their comment. But Dr. Koch was too busy even to listen to country gossip. He had to find some way of training the bacteria to remain fixed. But how?

"If I could somehow glue them fast — and yet I must not kill them. To find out how they cause us mischief, I must feed them, nourish them, and let them grow big and strong."

The doctor's eyes suddenly lighted. "Why must the bacteria roam in a liquid? Can I not make them thrive on solid food? And yet, how could I look at a microbe hidden away under a solid mass? Ah! I know. My microbe food must be transparent, so that I can look through it at the microbe itself. Perhaps if I make the food somewhat solid . . ."

He waited until some neighboring farmer was ready to slaughter an ox. Dr. Koch then set to work. Carefully he steamed a test tube for about an hour and a half. That heating was to kill any kind of bacteria that might be lurking in the tube. Then, when he felt sure that the tube was clean, he plugged the mouth of the tube with cotton wool.

"If my idea works, I shall be able to raise all the bacteria I need, and they will not move from the spot on which I put them. An ideal food — solid, and yet transparent," he muttered to himself as he hurried to the farmer.

"Is there anything you want, doctor?" the farmer asked respectfully.

"After you kill the animal, permit me to open one of its arteries. I need some fresh blood for my experiments," and he held up his test tube.

He carried the test tube, filled with warm blood, back to his laboratory, holding it all the way carefully, so as not to shake it. For a day he let the blood cool in the glass tube. The clear serum of the blood meanwhile separated itself from the coagulated thick blood. Koch added some gelatin to this serum so that it might become firm.

Now for the test. Would the anthrax bacilli like the new home he planned for them? Slowly he poured a few drops of this liquid on a smooth glass. In it he placed a drop of blood from an animal that had just died of anthrax. The jelly hardened and held the bacteria fixed. Yet the serum was so clear that Robert Koch could watch the germs to his heart's content.

His gaze was soon rewarded. The microbe had divided into two, and these two new bacteria were slowly growing. After a time these divided. "How rapidly they grow!" he wondered. His pencil scrawled some numbers on paper. "Suppose one of these bacilli were to divide into two in twenty minutes, and twenty minutes later, each new microbe reach the size of the original and then again divide, and then again, and so on, dividing every twenty minutes. In eight hours, we should have sixteen million germs! That's why these little rods are so dangerous. One germ can not harm you, but put it in the human blood, where it will thrive, and see what happens!"

Koch's idea was right. In a short time the serum was covered with little specks, each speck consisting of a whole colony of germs.

"I wonder if the bacteria like sunshine," he thought. He put them outside. Strange! He found that a ray of sunlight was like a glimmer of death to them.

II

A perplexing thought came to him. "If these bacteria are so delicate, how is it they can live in the fields, lurking in the grass and weeds of the open air?"

The question continued to plague him until one day an amazing sight gave him the answer. As he was paying his morning compliments to the microbe colony, a remarkable change came over it. All the rods and threads became little beadlike drops. Dumbfounded, Koch put these shining beadlike forms into fresh liquid, properly heated. Back again to rods and threads they turned.

"So that's it!" cried Koch. "These beads are the spores, the tough form of the microbe, the form it takes in the fields. In this guise it can withstand the dry and cold weather. When the cattle graze in the fields, they swallow the spores, which in the blood become those fatal rods and threads."

He felt confident that he was not mistaken. Writing to Professor Cohn, of the University of Breslau, a famous botanist, Koch asked the privilege of seeing him. "I have made a great discovery," he wrote.

Now Professor Cohn had received many letters from unknown men claiming that they had made great discoveries, but when he examined their claims, he usually found them false. Therefore he did not look forward to the visit of this country doctor.

It did not take Professor Cohn long to find out that Robert Koch could prove everything he asserted. Hurriedly he sent a messenger to the Pathological Institute, asking that some one come to his laboratory because a visitor, a Dr. Koch, had something to show which was "very interesting."

In the Pathological Institute, there was a great scientist, Professor Cohnheim. He went across to the Botanical Laboratory, where Koch was displaying his germs.

Back rushed the professor to the Institute. "Stop everything here, and go over to Koch," he shouted to his assistants. "The man has made a tremendous discovery!"

Koch's remarkable discovery, as he told them, was this: only an anthrax germ can cause anthrax; only a typhoid germ can cause typhoid. Every disease has its particular germ; and every germ is responsible for a special disease.

"But tell us how to stamp out this curse of anthrax," the farmers cried.

"Destroy the bodies of all animals killed by anthrax. Kill the bacilli," answered Koch.

III

The genius of the man who made so remarkable a discovery was recognized. He was made a professor of medicine and a member of the Imperial Board of Health of Berlin; he was given a fine laboratory there, and money and assistants to carry on his fight against all diseases. One by one he attacked each special germ. With the help of his assistants, he found and photographed the germs of eleven important human diseases, among which are tuberculosis, cholera, typhoid, diphtheria, pneumonia, and the bubonic plague.

He was to be found in almost any part of the world, exposing and destroying germs. Everywhere mankind was to be served. He went to Egypt and India to root out cholera and, thanks to him, that disease is now practically unknown in Europe and America. On the island of Brien, in the Adriatic, he vanquished malaria. Even when he was past sixty he traveled to a desolate island in Lake Victoria Nyanza to study the blood-sucking tsetse fly, which carries the germ of sleeping sickness. On this island he lived in a rough cabin, with only one companion, and their only means of reaching the mainland was a rough canoe, hewn out of a log.

Koch went to Egypt and India to root out cholera.

An idea of what humankind owes to Robert Koch may be gained from a few facts:

From earliest days, epidemics of bubonic plague wrought havoc over the face of the earth. During the fourteenth century alone this Black Death, raging in Asia and Europe, destroyed one-fourth of the population of the world.

Koch tracked down its germ.

Cholera had existed for hundreds of years in India, and at times had appeared elsewhere.

Koch, as head of a German commission sent to Egypt and India to investigate cholera, discovered the cholera bacterium.

His greatest triumph, however, was over tuberculosis, that disease under which so much human life had wasted away through long centuries. During the nineteenth century, over thirty million people died from it. From time immemorial every third or fourth adult, between his youth

and fifty-fifth birthday, succumbed to the Great White Plague.

"Tuberculosis is inherited," the doctors gloomily said. "If your father had it, you will have it. What can man do? Can he flee from his inheritance?"

But Dr. Koch was hopeful: "We are just beginning to understand diseases. Perhaps some germ is the mischief maker." He therefore looked at the blood of one of the tubercular victims. There he found tiny bacteria rods.

"These cause tuberculosis," he thought. "In a healthy man's blood I find no bacteria like these." However, he did not feel ready to announce his discovery, for he was thorough in all he did. To make sure, thought he, one must first be able to grow a microbe colony, and then he must see if these microbes really cause tuberculosis. Strangely, the germs died in the serum he prepared for them.

Robert Koch was perplexed. "I must try another kind of broth." But all attempts to grow the germs failed.

"That's strange. Why don't these bacteria like my broth?"

Then the picture of millions suffering, with their consumptive coughs and their expectation of death, determined him. "I must find a way to keep these bacilli alive. I must study the germ — to relieve mankind of such desolation. Since this broth doesn't suit them, I must experiment until I find some serum they will like and thrive on." The result of Doctor Koch's long and patient search was a special mixture of blood serum and glycerin. Now he could keep the bacteria alive. At least, so it seemed.

Ten days he waited anxiously before he could see the rods grow.

To Robert Koch the next step was all important. "Perhaps these germs do not cause tuberculosis after all. My eyes must see." Therefore he injected a speck of the germ

colony, which he had raised, into some healthy mice. Soon their blood was swarming with tiny rods.

"These bacilli cause tuberculosis," he could now announce to the world. Robert Koch had found the germ. And with his great discovery as a guide, doctors could lay plans to defeat the Great White Plague, even to prevent its start. Thanks to Koch, the death rate from tuberculosis has so fallen that we dare hope it may soon be a disease of the past.

He was, however, very modest in spite of his deserved fame. Like a true scientist, he said of his experiments, "They should be repeated by others to prove that I am right."

The Nobel Prize for medicine was given him in 1905, and the rulers of almost every European State showered honors upon him. When he died at Baden-Baden in 1910, the English journal, *Nature,* wrote: "The death of Robert Koch is a loss not only to Germany; all mankind is the poorer."

BARON JOSEPH LISTER

(1827-1912)

Surgery Made Safe

I

In Paris Louis Pasteur was still breathless with the vision of a new world. He was looking at tiny beasts toiling to change sugar to alcohol, to make milk turn sour and beer become bad.

At this time a young English doctor, Joseph Lister, was on his way to Glasgow to serve in the hospital there. As he journeyed, he pictured a wounded man brought to him, the poor fellow's face ashen, his eye glassy, and his mouth taut with agony . . . And then he drew a picture that flushed his grave brow, he saw himself examine the wound, heal it, and send the grateful man, saved from death, back to the bosom of his family with steady gaze and firm step.

Vain dream! Lister had no sooner begun his duties than it vanished. In the wards of the Glasgow Hospital he looked upon wounded limbs, stretched out, bearing bleeding arteries, swollen, oozing matter, rotting in their own filth; the patients exhausted with fever and pain. A heavy gloom and sickening odor hung about the dirty wards. Lister was horror-struck.

Glasgow was a large shipbuilding center, and accidents to the poor laborers were frequent. It might be only a deep cut from a tool or a broken leg that brought the worker to the hospital. It was nothing, he might think; in a week, perhaps, he would be back at work. But in a week the wound had become inflamed and swollen, putrid matter would trickle out, a fever set in, and death hover low.

Lister was torn with this suffering. But his fellow surgeons shrugged their shoulders. "There is nothing strange in this," they assured him. "We expect it. Blood poison and hospital gangrene kill half our patients."

"But can nothing be done?"

Again they shrugged. "It is not our fault," they answered complacently. "You see, the wound itself may be simple, but the oxygen in the air . . . "

"The oxygen?"

"Yes."

"Why? What does it do to the wound?"

"Oh," they made vague gestures. "Something or other. It inflames it."

Lister was dumfounded. What had the air to do with it? If it really was the air, then there was no hope. We cannot exclude the air. The workers in Glasgow must perish by hundreds. Industry must stop, for the air in a hospital did "something or other" that was fatal.

Lister could not believe it was the air, but he noticed one thing. If a patient came with a broken leg and the outer skin had not been cut, he recovered. But if the outer skin was severed and the wound an open one, the patient was doomed. At that very moment, Pasteur was observing that when a fruit had its skin bruised, it became rotten at once.

"These hospital diseases, gangrene and blood poisoning!" exclaimed one surgeon. "Take the patient out of the hospital if you would have him recover. Take him to the church! Take him to the schoolroom! Take him to the stable! Anywhere but to the hospital, for that will be his grave!"

II

One day in June Lister, very much depressed, was walking home with his friend, Tom Anderson, who taught chemistry.

"I can't understand it," worried Lister, his lofty brow darkened. "I suppose I never shall understand it. A wound putrifies. Why? I cannot help thinking that the man who is able to explain this problem will gain the world's undying blessing."

"Don't be discouraged," his friend said. "You may be the man." And then as if by a happy chance, he asked, "Have you read the papers of Louis Pasteur?"

"No, who is he?"

"A French chemist who has written very brilliantly on the subject of fermentation. He says that there are microbes . . . "

Thus Lister came to know of Pasteur's theory. Like a vast white light, Pasteur's words flooded him. Like a germ the theory infected him, driving him to tramp restlessly in the night air, struggling on the verge of a discovery. His heart leaping, he said, "The same thing that sours milk and ferments the crushed grapes must also rot the raw flesh and putrify it. Microbes! Not the air but the dust in the air, bearing this tiniest creature to do its deadly work; or the hands of the surgeon, carrying the bacteria from one wound to another."

"Microbes . . ." he gravely told the other doctors.

Really, they thought, it was a pity that a fine fellow like Lister should take the crazy Frenchman so seriously.

"Microbes," he went on unafraid, "are like vultures hovering over a fallen body. Bacteria are more deadly than bullets."

"Yes, yes," they said sarcastically.

But he did not mind their thrusts, the gentle soul; he pondered how to kill the bacteria in a wound and then to prevent them from entering. That was a tough problem. It did no good to know a fault, if one were not able to correct it.

One day Lister saw this heading in a newspaper:

CITY OF CARLISLE GETS RID OF SEWAGE

Carbolic acid sprinkled on sewage kills odor

He was off to Carlisle in an instant, to make sure. "The fetid odor of sewage," he reasoned, "is like the fetid odor of a putrified wound. Both spell bacteria. No odor, no bacteria. What kills one, kills the other."

He forged the first great antiseptic weapon: carbolic acid. The doom of the microbe was at hand.

Lister forged the first great antiseptic weapon.

III

A year later a startling contrast set the world agape. There were two accident wards in the Glasgow hospital. In one, as of old, the air killed many; the agony was so heart-rending that the ward had to be closed. In the other, separated from the former by a corridor only twelve feet wide, there had not been a single case of blood poisoning or hospital gangrene. That was Lister's ward.

The astounded world flocked to Glasgow to congratulate Lister, to do him honor, and to learn from him. "I have done nothing," he said with sincere modesty, "but the antiseptic treatment does wonders. I keep a wound saturated with a mild solution of carbolic acid. That kills the microbes, and keeps the wound fresh and sweet. Nature does the rest."

They watched him at work. What a different place his ward was from the old hospital room! Instead of the fetid odor of decaying flesh, the fresh, sunny air prevailed and the sunshine came cheerily in. Instead of patients with wan, pinched faces, praying for death to deliver them from pain, these patients were radiant with hope and relief. Instead of being carried out in coffins, they walked out, restored in health. Instead of fear of the surgeon, they felt a boundless gratitude for his blessed hands.

"He likes the little yins best and the auld women," whispered a street urchin as Lister passed his bed.

In later life, his students said that contact with him was of the best and purest in life. The only time a rebuke was known to come from his lips was when a young student of his lifted a broken leg a little too roughly. "A feeling heart is the first requisite of a surgeon," he said.

To the poor he was as tender as to the rich. He operated on Queen Victoria and the humblest beggar with the same care. The famous poet, William Henley, who was a patient of his, was inspired to write a beautiful sonnet about him, called "The Chief", which closes with the lines:

Poem [illegible]

"His wise, rare smile is sweet with certainties,
And seems in all his patients to compel
Such love and faith as failure cannot quell;
We hold him for another Heracles,
Battling with custom, prejudice, disease,
At once the Son of Zeus with Death and Hell."

The whole world paid him homage. The queen knighted him; he was appointed to the House of Lords — but all this meant nothing to the man who had given up riches, that he might devote himself to the mighty task of destroying pain and disease. This he did as only a handful of men in the history of the world have done. If it had not been for Lister, every year thousands would be dying. The hospital of to-day, surgery of to-day, we owe to him.

"Why do you talk of germs!" was rudely demanded of Pasteur. "What are they? Show them to us."

And although stormy debaters surrounded Pasteur and shattered his nerves, Lister did not need to be convinced. He saw in a flash. Always modest, he wrote to Pasteur: "Allow me to tender you my cordial thanks for having demonstrated to me the truth of the germ theory of putrefaction, and then furnished me with the principle upon which alone the antiseptic system can be carried out."

At the Pasteur Jubilee in 1892 in Paris, Lister arose and turning to the old Frenchman said, "Thanks to you, surgery has been stripped of its ancient terrors and has thus enlarged without limits its power."

At these words, Pasteur could not contain himself. Springing up, he hurried to Lister and taking him like a child by the hand, led him to the center of the platform and there embraced him, while the spectators thundered applause and shed tears at the sight of those two brothers in science who were laboring to lessen the sorrows of human life.

IV

Before Lister, the greatest surgeon was a remarkable Frenchman, Ambroise Paré, who lived some four hundred years ago. It was Paré who dreamed of changing surgery from the terror that it was and the last hope of the dying

man, into a way of healing. It was Lister who completed Paré's work and at last made the dream come true.

Paré was the medical genius of his day. Prince and pauper alike were happier because he lived. But his fellow surgeons were bewildered. In every meeting of doctors, his amazing career was rehearsed, somewhat as follows:

First Physician: Say! Have you heard about that surgeon in the army of our King Francis?
Second Physician: No, what about him?
First Physician: He has discovered a new way of dressing wounds.
Second Physician: Really! Is he a member of one of the surgeon guilds?
First Physician: That is the amazing thing. He is only a barber-surgeon.
Second Physician: But what can a barber know? He might know the remedy every soldier uses for gunshot wounds — that drink of gunpowder stirred in water — but . . . Can this barber read Latin?
First Physician: No. He admits he knows neither Latin nor Greek.
Second Physician: Then how did he study his Galen? What can be his discovery?
First Physician: I'm coming to that. You see, he was apprenticed in the usual way to a barber. Like all apprentices he swept and opened the shop at daybreak. Then he would comb wigs, singe beards, and shave. Toward evening he might want to read. But even then, you may imagine, a customer might interrupt to have his hair cut.
Second Physician: Well, when did he learn surgery?
First Physician: Do you not know that the University Professors are kind enough to lecture to apprentices in the small hours of the dawn?

Second Physician: Certainly, but lectures are in Latin. It is below the dignity of a physician to lecture in the language of the common people. You said he knew no Latin.

First Physician: Oh, probably some one explained to him what the professor said.

Second Physician: Probably. You still have not told me what great discovery this Paré made.

First Physician: I'm coming to that. Well, he joined the army. There he learned his surgery by using his eyes and his hands. Don't laugh. He managed to learn something that way. He learned, for instance, that you treat gunshot wounds by scalding them with the painful oil of elders.

Second Physician: In the name of Esculapius! What did he discover?

First Physician: I'm coming to that. Once he happened to run short of oil, when he had some wounds to dress. He was in a panic. They say, you see, he is a very kind soul. But what could he do? He was forced to apply something else to the soldiers' wounds. Here is his discovery. He made a mixture of the yolk of eggs, oil of rose, and turpentine, and applied that instead.

That night he could not sleep. You see, he was thinking, "I should have made that mixture scalding hot. I shall certainly find my poor patients dead." But in the morning strangely enough . . . You see . . . Well, well! Don't get angry. I'm coming to it. Paré found that those whom he treated with his new mixture had but little pain, and their wounds were without inflammation or swelling. They had rested fairly well that night, and were recovering. But the others, on whom the boiling oil was used, were feverish with great pain and swelling about the edges of their wounds. That is his discovery: never more to scald a poor patient suffering from a gunshot wound.

Second Physician: So! But that was accidental. I wouldn't say Paré made a great discovery.
First Physician: Oh, forgive me. That is not the discovery I was going to tell you about. That is not the *great* discovery. You see, for instance, he heard of a surgeon famous for his treatment of gunshot wounds. Paré wanted to learn the treatment, but the greedy surgeon would not tell. For two whole years Paré coaxed. You see, he wanted to know everything. And who could tell him? Maybe the secret was worth while. At last, thanks to his persistence and his presents, Paré got the cure from the scoundrel: take oil of lilies, earthworms soaked in turpentine, and whelps just born. Boil these together! You may imagine that such twaddle did not satisfy Paré.
Second Physician: But how about the *great* discovery?
First Physician: Oh yes. I was just coming to it. He had to find some way to stop the flow of blood when a limb was amputated. Paré says that two out of every three die, because they lose so much blood during the amputation.
Second Physician: Nonsense! A red hot iron will wither the artery, and the blood will no longer flow.
First Physician: But think of the horrible suffering! Even those who do escape death are sick for a long time, and the wounds thus burned are slow to heal. For the burning causes such vehement pains that the patients fall into fever and convulsions. And in most cases, when the scar falls off, bleeding starts afresh. What do you do then? Staunch the blood again with a red-hot iron? Why, the flesh is seared to the bare bone, so that healing is impossible. And in such cases, ulcers develop and make the end of the patient's life an agony.
Second Physician: Will you or will you not tell me the great discovery?
First Physician: Now I've come to it. Instead of sealing up the artery by burning, Paré simply ties it. The blood no longer flows, and the patient is no longer doomed.

For three hundred years after Paré no further progress was made. Yet the piece of silk tied round the cut end of an artery had a great fault, as Lister found. It was not free from germs. Pus formed and kept on forming until the silk cord was removed. This was done by leaving the long ends of the cord hanging, so that, when the knot had rotted away through the artery, the silk cord was pulled out. Meanwhile, the patient's strength wasted away under the infection, and death was almost inevitable.

Doctors were in despair. When they amputated, they must go back, it seemed, to the barbarism of burning the artery. Then came Lister, with his belief in germs and his simple weapon of carbolic acid.

Once he was treating a man for a fracture of a bone. As usual, he washed the wound with carbolic acid. Looking closely one day under the crust formed on the wound he saw a tiny cavity, filled with a brownish fluid. As Lister touched the edge of the crust, it began to bleed!

"How can the crust bleed?" Lister wondered. "It is not flesh."

But it was. The healthy, live tissue around the crust had begun to grow, and had eaten up the dead matter. "If living tissue can eat up dead blood crust," cried Lister, "why should it not eat up the silk cord with which I tie the artery? My carbolic acid will keep it free from microbes. I won't need long threads left hanging out of wounds. I shall cut the ends short. The wound will close, and the silk binding will be absorbed by the living tissue around it."

That is exactly what happened. The silk ligature disappeared very slowly.

"Silk is not the best material for ligatures. I must try something else." He chose catgut, finally, a thread made from the small intestines of a sheep. He tied an artery with it. Shortly, the gray of the catgut turned to pink. The flesh had digested the gut very easily. Lister had succeeded.

To-day the surgeon who ties an artery with catgut is thankful to Lister. And the feeling of mankind for the great man was well expressed by Mr. Bayard, the American Ambassador, at a banquet the Royal Society once gave in Lord Lister's honor: "My Lord, it is not a Profession, it is not a Nation, it is Humanity itself, which with uncovered head, salutes you."

GENERAL WILLIAM CRAWFORD GORGAS

(1854–1920)

The New Soldiership

I

At break of day a message was sent to Doctor Gorgas. "Her Ladyship is in a critical condition. Come at once," the message said. Doctor Gorgas dressed hurriedly, and soon arrived at her home, a large glass jar. He found Her Ladyship lying on a bed of cotton wool surrounded by several nurses. She was very beautiful; her body was marked by silver half-moons; her thorax, by four brilliant stripes; and her legs were striped black and white.

Her Ladyship was beyond the pale of medical science. That evening she finally died with as many doctors and nurses attending her as befitted her station in life.

For she had been a member of an aristocratic family, the Stegomyia, the most important mosquito in the world — the mosquito which carries the yellow-fever germ in its body. When it bites you, it leaves the germ with you; and then death is not far distant. Her Ladyship had been probably the most vicious of her kind. In her little body she had carried the yellow-fever germ around so long that she had become a living laboratory of the disease, which the doctors were then studying. Therefore Doctor William Gorgas and his associate, Doctor Walter Reed, mourned Her Ladyship.

The yellow-fever germ has played a greater rôle in history than many a king. For human slaughter it is more

illustrious than Napoleon or Alexander. On the island of Santa Lucia in 1664, for instance, all but a handful of men out of an army of about ten thousand perished without so much as knowing the real enemy.

Once by itself it was the unconquerable army and navy of the West Indies. In 1762 an expedition of English and Colonial forces seized Cuba. After a few months' occupation, the force was utterly routed — by the yellow-fever germ. In 1800, Napoleon sent his best forces to Haiti. In less than a year, the army, with livid faces and black vomitings, was destroyed. Guns were of no avail; soldiers served only to fill graves; and the inhuman enemy remained invisible and majestic. Yellow fever was the real reason why Napoleon sold us Louisiana.

In 1793, a yellow-fever epidemic broke out in Philadelphia. There was scarcely a home without its dead member. Unburied bodies lay in the streets. Everybody who could fled from the stricken city. Yet the toll was four thousand lives.

In 1882, the yellow-fever germ made a fatal mistake, for which it eventually paid with its life; it attacked William Gorgas and failed to kill him. This made him immune, in the way Pasteur had discovered.

As a child William wanted to be a soldier. But in his manhood he realized that the greatest war was again disease and ignorance. Therefore he decided to be a doctor. It was the time of Pasteur, Koch, and Lister. "Look for the germ," was the cry, and Gorgas took it up. He was, besides, one of the first surgeons to practice Listerism in America.

II

Our country had suddenly awakened to a grave trouble. Spain had played a grim joke on us. She had withdrawn from Cuba, and we had gone in only to find that we would

have to retreat. Our men were being massacred outright. Languor and chilliness seized them, headaches and muscular pains. "Notice the peculiar look of the eyes, the flush on the face, the scarlet tongue. Yellow fever!"

Then came the fever heat, with its thirst and hot skin, its restlessness and its delirium. Anxiously the doctors waited for the next stage of the illness — the cold skin, lemon yellow in tint. Would the patients recover or must they die? Cuba, it seemed, would have to be abandoned to that invincible enemy — the yellow-fever germ.

In despair the government had sent to Havana Gorgas and a few other soldiers of science. The shadow of gloom, however, came over Gorgas and his fellow doctors, who were ready to give their lives for the cause. And there was good reason for gloom. Doctor Gorgas had seen that the putrid streets of Havana were made spotlessly clean, and proper sewerage built. The stinking city, over which had hovered black vultures swooping down on the filth, had changed its dress and was for once spotlessly clean. Why then did yellow fever continue to mock the labors of Gorgas? The pestilence had grown worse, if anything.

"You have failed," said an old doctor to him, "and you will fail. Listen to me. The cursed mosquito, the Stegomyia kind, is at the bottom of the trouble. I can't prove it, but I *know* I'm right. It's the mosquito."

Gorgas listened doubtfully, but he thought: "There may be something in this idea about mosquitoes. Let us find out."

"I'll let the mosquito bite me," said his friend Doctor Reed, "and if I fall victim to yellow fever, you, Gorgas, will know how to carry on the fight."

But the government would not allow this; Doctor Reed's life was too valuable. It was useless for Gorgas to offer himself because he was immune. Two other doctors of the heroic band, however, thought, "How can we die better

than in the cause of science?" And they let a mosquito which had bitten a yellow-fever patient, bite them, too. In a few days they were in the clutch of death.

Perhaps it was true then. Perhaps the Stegomyia mosquito did carry the yellow-fever germ from one person to

"The mosquito, the Stegomyia kind, is at the bottom of the trouble."

another. But it was not certain yet. Maybe the two victims had caught yellow fever elsewhere. More men were needed for this dangerous experiment. A call for heroes was sent out, "You who are willing to sacrifice your lives that humanity may be free from the curse of the yellow fever, where are you?"

Into Doctor Reed's office one day stepped two unknown men. They were just plain citizens from Ohio, just plain John Kissinger and James Moran. They were willing to help, they said simply, if they could be of any use.

"You realize what you are doing, don't you?" warned Walter Reed. "You may die."

Kissinger and Moran nodded. They knew that. They were quite willing. Two more heroes had entered the struggle to aid humanity.

Both men were secluded in a house for weeks, to make sure they could not contract the fever in any other way. Then the dreaded Stegomyia mosquito was let in to stick its proboscis into their flesh. Three days later the already-overcrowded yellow-fever ward received two new patients, John Kissinger and James Moran.

There was no doubt now in the mind of Gorgas and his band, but everybody else was scornful. A mosquito, so weak and little! Ridiculous!

The people were gloomier than ever. "Even if it is true," they said "what good does it do to know that mosquitoes deal death? We cannot get rid of them. We might as well try to get rid of the air."

But William Gorgas was a determined man. "If it is the mosquito," he said simply, "we *will* get rid of it."

He was jeered roundly. "What! You want us to act like lunatics, hunting mosquitoes? Be reasonable! Besides, we can't kill all the mosquitoes in the world."

"Perhaps not," he replied quietly, "but we can try."

He began warily to study the habits of the enemy. He found that the Stegomyia mosquito is a tame insect. It will not live away from human beings. It refuses to lay its eggs anywhere but around a house, in a container of water.

"Swatting the mosquito will not answer," reasoned Gorgas. "I must strike the mosquito at its source — by destroying its eggs. Then no mosquitoes will hatch. But how can I crush these minute specks floating on water?"

Here was a puzzle indeed: to wage war against an unseen foe. Gorgas pursued the matter, "What is the weak

spot of the enemy? There one should strike. The more we know about his habits, the easier will it be for us to win."

"Instead of stamping out yellow fever, Gorgas studies mosquitoes," some government officials muttered. "As if an insect could have anything to do with disease!"

But Gorgas was learning many curious things about the mosquito. He found that the mosquito egg first hatches into a wormlike wriggler, which lives in the water. The wriggler grows until it is about a quarter of an inch long; then it changes to a mosquito. One day, as he watched these wrigglers, Gorgas discovered the weak spot of the enemy. The wrigglers had to come to the surface of the water for air.

His heart beat fast as he realized that at last he held the key to the problem. "If I prevent these wrigglers from coming to the surface of the water, they will suffocate. Now, how can I prevent this? How can I cover the water?"

"With oil!" That answer came to him. "Oil and water do not mix. The oil stays on top. It will not spoil the water for us, therefore, and to a wriggler it will be like an iron wall between him and air. A little oil on the water and the imprisoned wrigglers will soon die. Then there will be no mosquitoes, and no yellow fever."

"Leave no container of water uncovered. Pour a little oil on all standing water," was his order.

"Never leave a basin of water standing!" exclaimed the Cubans. "Gorgas is crazy. We will do what we please about it."

But Gorgas was a kind man. He did not order them to act, although he had the authority to order. He simply explained, showed how such a procedure was for their own good, and pleaded with them as a friend to trust him. The Cubans loved and respected him for this kindness, and devotedly they helped him.

Gorgas organized a health army. The soldiers were in-

spectors; their weapons, pails of kerosene. In every district, you could see the inspector armed with a pail of kerosene, looking for tin cans, water barrels, and tanks. Every building in Havana was visited each month, and every possible place in it where water might have gathered was carefully searched.

"Your work is useless," a doctor from Havana told Gorgas.

"What makes you think so?" asked Gorgas.

"I've emptied every container of water in my house. Yet there are plenty of mosquitoes."

"Let us look," suggested Gorgas calmly.

Sure enough, after a long search Gorgas discovered a small pail half full of water, tucked away, unsuspected, in a closet.

The task of destroying all the mosquitoes in Havana was indeed tremendous. Yet Gorgas and his friend Doctor Reed succeeded perfectly. A few figures, and the story of Gorgas comes to a happy ending. Before the time of Gorgas, for about one hundred fifty years, there was not a day without a case of yellow fever in Havana. In 1896, there were twelve hundred eighty-two deaths. Since these heroes won their campaign, there has not been a single case of yellow fever on record there.

III

After Cuba, Panama was the problem facing the United States. The French had failed to construct a canal there, because yellow fever had destroyed its workers as fast as they were sent. And now the United States had possession.

To go to work in Panama was almost like committing suicide. Workers coming from America sometimes brought along their coffins. Funeral trains were more common than

freight or passenger trains. The horror grew so great that it seemed as though the Atlantic and Pacific Oceans would never be joined; that Panama would have to remain the jungle home of beasts and snakes. The Stegomyia was doing its terrible best.

The president dispatched the great yellow-fever fighter to Panama. Everything depended on Gorgas. But to the admiral, in charge of Panama, this great man and his mosquito theory was a joke. Gorgas was hindered and checked wherever he went. He was refused supplies and, despite his warnings, was disobeyed and ridiculed.

In November, 1904, the fun started. The lurking Stegomyia was on the warpath. Officials and laborers were in the trap together. Work on the Canal stopped. Those who could fled in terror, only to be caught in their tracks. New arrivals from the United States sailed home the same day they arrived. The loss of life was pitiable. Gorgas could but watch sorrowfully. The Canal seemed doomed.

Humbly the officials turned to him. Now they heeded Gorgas in every order: "No exposed containers of water. Beware the mosquito."

The disease began to slacken its pace. Its victims became fewer and fewer, until one beautiful day in 1905, the final case of yellow fever was over in the Isthmus. Gorgas had at last wrested the Panama Canal from its ancient lord, yellow fever. His prophecy has been fulfilled. The Canal has been built, and from 1905 to this day not a single case of yellow fever has been contracted there.

IV

The final chapter in the story of yellow fever is one of tragic glory. Yellow fever and its evil sign, the black vomit, troubles us no more, but in the last and greatest struggle with it, Hideyo Noguchi, the Japanese hero, gave his life.

It happened in this way. The yellow-fever germ had come, ravished millions of lives, and then been driven off by Doctor Gorgas and his band. But as yet no one had ever seen the germ. "Look for the germ," had counseled Pasteur. Gorgas and every other scientist had looked for the yellow-fever germ, but in vain. It remained invisible. Doctors began to doubt that there was a germ causing the black vomit.

"Maybe Pasteur has gone too far. Maybe there are some diseases which are not caused by a germ. Yellow fever, perhaps, is caused by the Stegomyia mosquito itself."

The great scientists did not doubt; they believed in Pasteur. That caused them to be worried by the invisible germ of yellow fever.

"No," Gorgas had said, "the mosquito is an innocent host, which gives lodging to the real criminal. For some reason this invisible germ lives best in the body of the mosquito. Then, when his host lights on human skin to sip a bit of blood, out slips the germ to do its deadly work."

"Well," replied the doubters, "prove it. Show us the germ."

That none could do, and there the mystery hung for a while.

In 1918, the province in Ecuador called Guayaquil sent out a cry of distress. It was the old story. The invisible peril had laid its hand heavily on the people of Guayaquil and was spreading its destruction. Again the black vomit: again the strewn bodies.

In America the Rockefeller Institute heard the cry and sent down a little group, among whom was the brilliant doctor, Hideyo Noguchi.

Just about the time when Pasteur was working on the cure for rabies and Gorgas was poring over his medical books at college, Hideyo Noguchi was born in a small town in Japan. His home was a hovel, and had it not been for the charity of a friend, he would never have gone to the

schools in Tokyo and later in America. He showed such remarkable power as a student, that the charitable friend thought it would be a pity not to help him on until he became a doctor. But he was more than an ordinary physician. He gained such knowledge in the science of disease that the Rockefeller Institute invited him to work on its great problems. And what a worker he proved to be! Once he started on an experiment, his friends knew, there was no use trying to lure him out of his laboratory. He scarcely ate or slept.

So, with his test tubes and microscope and a crate of guinea pigs, he landed in Ecuador.

"Gorgas was right," he at once remarked. "First of all, death to the mosquito! And as for your sick ones — do not move them, and give them no food and plenty of water."

The scene in Havana and Panama repeated itself in Ecuador. "No standing water!" was the order. And good inspectors were there, too, to see the order carried out.

Meanwhile Noguchi was working in his laboratory at the seemingly impossible task of finding the germ. He let one of his guinea pigs contract yellow fever. Then he took some of its diseased blood, filtered it, and thought, "Now the germ ought to be on the filter." When he put the filter under the microscope, however, there was as usual no sign of the elusive germ.

"An impossible task!" he seemed to hear repeated.

Suddenly it flashed into the mind of Hideyo Noguchi that perhaps the germ is so small that it slips through the filter. "No wonder we haven't found the germ," he cried. "Perhaps we have been looking in the wrong place. Besides, it may be so small that the ordinary microscope fails to show it."

So he proved. Before long, using what is known as a dark-field microscope, he was able to unmask the wriggling pest.

"Now," thought Noguchi elated, "let us turn this villain of the centuries into its own enemy. Let us see about making a vaccine of it, as Jenner did with smallpox, to prevent yellow fever, and then a serum to cure it."

He had the vaccine ready in a short while. "Will it work, though?" was his anxious question. The test was before him. He vaccinated about one thousand soldiers and sent them into Guayaquil where the disease was still raging. And the results?

"Noguchi," his comrades said warmly, "you have won. You have conquered yellow fever."

"But the results?" he inquired impatiently.

"Only eleven of the one thousand soldiers have contracted the disease. Congratulations!"

"No, no!" protested Noguchi. "I have not succeeded. I have failed."

Back he went to his laboratory. "The vaccine must be stronger," he decided.

During the years 1920 and 1921, ten thousand people in the yellow-fever districts of Mexico, Salvador, Guatemala, and the British Honduras were vaccinated with Noguchi's new vaccine. And the results? Every one of the ten thousand remained safe. Noguchi saved them — and millions after them.

In gratitude the government of Ecuador offered him a large estate and a fine laboratory if he would only consent to stay with them. Noguchi refused. Wealth meant nothing to the modest scientist, and he returned to the United States. But in Ecuador there is a *Calle Noguchi,* and an airship *Noguchi,* and a bronze monument has been raised to him. Not only through Ecuador did his name ring. The whole world celebrated his success.

What Noguchi had done for yellow fever, he now set out to do for hydrophobia. For that disease Pasteur had found the cure but, just as in the case of yellow fever, the

germ of rabies had defied detection. It continued to attack and retreat in a cloak of invisibility. That was before Noguchi began his work of hunting it down. It does so no longer.

"There!" Noguchi was able to cry, pointing to the swarm of hydrophobia germs under his microscope. "There is the terrible pest, helpless at last."

So the labors of Pasteur and Gorgas both were turned into complete triumph by Noguchi.

All at once, in 1927, the shadow of death fell upon a large area on the west coast of Africa.

"Yellow fever is abroad again," the doctors in Akkra cabled. "But it is not the yellow fever that we know. It is in a strange guise, or perhaps it is a cousin to the black vomit of America. We do not know, and we are helpless."

There was one man to whom every one looked — Hideyo Noguchi. And he was ready to go.

He had been working hard, and as he said farewell to his friends, he seemed a bit tired and his eyes flashed a little more brilliantly than usual.

"Perhaps he should not go at this time," thought his friends uneasily. "At least not to Akkra, which is one of the most unhealthy spots in the world."

They waited for news, and the worst came. The great man had hardly been welcomed in Akkra, he had hardly begun his work, when he was stricken down. He who had saved so many millions of people had not now the strength to fight for himself. On May 21, 1928, the tragic news flashed around the world, "Hideyo Noguchi — a martyr!"

ELIE METCHNIKOFF

(1845–1916)

Our Body's Defenders

I

"I AM quite willing that you should go to college," Illia Metchnikoff reasoned with his young son, "but I don't see why you dislike Kharkhov University. It is right here in Russia, near home. Why must you go to a foreign country? Besides, it is cheaper to study here."

"But, father, I am interested in zoölogy. I want to become a scientist, and I cannot learn science from books. I must experiment, and for that I need good laboratories. Everybody knows that for science one must go to Germany, to the great universities there. Now in the University of Würzburg I can study under the direction of that great zoölogist Kölliker. Mother thinks I'm right, don't you, mother?" pleaded the boy.

His mother rewarded him with a smile. Then she nodded her head, and said, "Let me discuss it with father. I think we might be able to arrange it." She had long hoped that her boy would some day be a great scientist. But she knew the weak side of her brilliant son — how erratic, how whimsical, he was. The fond mother, however, convinced her husband that though they could not afford it, they must make the sacrifice for their son.

The boy had his way. The express train to Germany seemed to move very slowly, as he visioned the university where he could learn so much. First he was going to Leipzig, the book center of Germany. He had a notion that he

must buy his books in advance, so he could be prepared right away for the professors' lectures.

Late one evening he stepped off the train at Leipzig. Bewildered, he looked about him. He was far from home, and it was dark. Where should he turn in the strange city? Luckily a kindly German at the station saw the boy's plight. Elie eagerly told him what had brought him from Russia.

"Come with me. We'll be able to put you up for the night," the stranger offered. Gratefully Elie Metchnikoff accepted.

Very early the next morning the boy awoke. He could scarcely wait for the book stores to open. He bought his precious books at last and, hugging them close, turned to go to the house of his kind host. Where was it? He remembered neither the name of the street, nor the number of the house! Only after great difficulty did he find his way back, breathless and frightened.

His greatest misfortune, however, was in store for him at Würzburg. He arrived there at the wrong time, during a school vacation, and once again was stranded in a strange land. He would have to wait six weeks, he was told, before classes began. What was he to do, all alone? If he only could meet some friendly Russian students, perhaps he would not feel so lonely. But just that first morning he met no one who was friendly.

In low spirits he set about finding lodgings. That depressed him more. Finally he engaged a room, dragged his baggage up the stairs, and began unpacking. All at once the room seemed to grow loathsome to him, and the landlord, disagreeable. His heart was breaking with homesickness, and gloom was gathering about him in mists. Frantically he packed up his things again, flew to the railroad station, and took the first train home.

Elie Metchnikoff's first trip abroad had ended in failure.

II

Years later, in a deserted quarter in the town of Geneva, one night, Doctor Metchnikoff stole shivering from his lodgings. A thin shirt open at the neck was all the protection his weak chest had from the cold night air. As a strong shuddering seized his chilled body, he thought with morbid satisfaction, "I shall succeed this time. The poison failed, but a hot bath followed by such exposure to cold is better than all the poisons in the world to one who wants so much to die. Pneumonia spares but few."

Die he must. What had he to live for? Death had just taken his beloved wife, and left him bitterly alone. His one consolation, his science, was denied him, for his eyes had rebelled from the abuse of too much study. That was the penalty he was paying for peering since childhood through microscopes. Then why live?

True, he was admired. Scientific journals had been printing what he wrote ever since he was fifteen. All the universities in Europe knew him, for to study with the teacher he wanted, no distance had been too far to go. Russia, Germany, Italy, France — in all their laboratories he had worked and studied. To find a new specimen of plant, fish, or insect, he had traveled a thousand miles. As a professor at the University of Odessa at the age of only twenty-two, his students all older than he, he had been greatly admired.

But now it was all over. When he became blind, he could no longer work; his darling was dead; why should he go on?

"Ah . . . " he shivered as he approached the Rhine bridge.

Suddenly he stopped. About the flame of a lantern a cloud of winged insects were flying.

"Ephemeridae," he reflected, "they must be. They do not eat, and only live a few hours. They do not have time

to adapt themselves to their surroundings. How can Darwin's theory of natural selection be applied to these insects? I must go home and work on the problem. Heavens! It's cold!"

And forgetting all about suicide, he hurried home. His thought had turned to science. He was saved.

Eighteen years later he was enjoying the lovely seacoast of Messina. Life was good to him once more. He no longer had to fear blindness. The fragrance of tropical flowers floated on the soft breezes; and from his window he could see the faintly blue waters, lapping gently on the sands and teeming with all kinds of fish life.

Metchnikoff was examining a beautiful specimen of a starfish. The simple animal, being transparent, was a fascinating sight; and Metchnikoff was watching it digest its dinner, a few grains of dried carmine which he had prodded into the outer layer of the flesh. A queer process was going on. Tiny round body cells were detaching themselves from the body of the fish and were tending toward the grains, were gathering about them, slowly surrounding them, engulfing and digesting them.

"Queer food for a starfish," thought Metchnikoff, "and a queer way of eating it. Why do these particular cells, and no others, float so swiftly to devour the grains? The poor fish must be very hungry or not very self-respecting to eat such stuff, unless . . . "

Like a flash, a great idea struck him. He rushed out into the garden. He picked a few rose thorns from a tangerine tree decked for Christmas. Back he rushed to the starfish, and into its outer skin he poked the thorns.

"Now," he whispered to himself, "if it eats the thorns with the same cells, it can't be for want of food. It must be for some other reason."

He would have to wait till morning to find out. He could

To find a new specimen, he had traveled a thousand miles.

not sleep. He could not rest. He was in a fever of impatience; so much hung on the outcome of this experiment.

Dawn! He jumped out of bed and ran to look. A shout of joy rose to his lips. The thorns had been completely absorbed.

"That settles it," he cried. "Those cells are the body's defenders. They devour intruders, not for food but for protection. They are the home defense against invasion."

Every animal must have these defenders, Metchnikoff announced, or else it would be killed very shortly by those preying vultures, microbes. In man, the defenders are the white corpuscles, which migrate through the walls of blood vessels and come from the far ends of the body to attack the foreign intruder, be it a dead splinter or a live microbe.

Suppose a microbe has entered your body through some break in the skin. Instantly, like a well-trained army which can be mobilized at short notice, the white corpuscles

hurl themselves on the attacking microbes. The fight is on. Like a burning sky, reflecting the flame of the battlefield, the site of the struggle in the body becomes inflamed. The wounded corpuscles give forth a liquid, pouring forth their life in it — pus. If they vanquish the enemy microbes and eat them up, the body is cured. But if they are destroyed by the microbes, the body may die. A savage battle of cannibals!

These devouring cells, or phagocytes, as he named them, using words from the Greek, the scholar's language, — "these phagocytes," thought Metchnikoff, "can be trained to win the battle, no matter how strong the attacking microbe."

Pasteur agreed with him.

"You have explained to me," Pasteur said in appreciation, "*why,* when a person has had a mild attack of a disease, he cannot get it again. You have explained why my vaccine works as it does, to give immunity. It is all because the phagocyte has already fought the enemy, and is inured to it."

Lister agreed, too, and Koch became convinced. They all saw that the phagocyte is not always at first strong enough to fight a virulent microbe, but by giving the phagocyte a weakened microbe first — as Pasteur gave his chickens the weak cholera microbe — the phagocyte becomes used to overcoming and eating it and is able to cope with the stronger of the same family of microbes later on.

III

The great Frenchman admired Metchnikoff so much that he gave him a fine laboratory in the Pasteur Institute. "You are on the right track," he said kindly. "Perhaps you will do still greater things."

They became fast friends, seeing each other every day.

In his laboratory, Metchnikoff received doctors from the whole world who came to be his enthusiastic scholars. The fiery teacher was not satisfied with his accomplishments. His eye kindling with a far gleam, he would repeat, "Work, work, let us increase happiness. We can banish all disease, even" — he whispered this as in a vision — "death."

This unbelievable godlike task, the dreamer set himself. "At least," he insisted, "we can learn to put it off to the time when the body longs for the sweet repose of death; when death is as welcome as the deep sleep at the day's end."

When his awed students asked how he meant to ward off natural death, he replied, "Old age comes when the cells in our body's tissues grow weak. When they are weak enough, the phagocytes turn traitors and cowards, and eat them up as they do the enemy microbes. With my own eyes, I have seen the phagocytes of a tadpole eat its tail up, as the tadpole turned into a frog which needs no tail, having legs."

"But what makes the cells weak?" they asked.

"Well, there are multitudes of microbes hiding in us, in a place where they are safe from the phagocytes. The home of these marauders is the large intestine. From this hiding place they distil their slow poisons which weaken the cells of the body.

"These weakened cells cannot defend themselves. Therefore they become the prey of the microbes. For instance, one of the first signs of old age is the whitening of the hair. Why? Because the tiny organisms actually eat the pigment of the hair."

"And the cure, professor?"

Swift as a flash came the response, "To introduce into the camp of the enemy, into the large intestine, other microbes, friendly ones, which will destroy our enemies and do us no harm. Old age is a disease caused by microbes.

Perhaps we may never be able to cure it entirely, but we surely can find some means of postponing it."

He experimented and found a certain microbe which he thought would help us in our fight with old age. This friendly mite will grow in milk, which it turns sour. "Why," he asked himself, "are there so many people one hundred years old in Bulgaria and among the barbarous tribes of the Tartars and Kalmuks? What do these people eat and drink that gives them long life? It must be the milk which they make sour, in the same way I shall sour mine."

"Metchnikoff milk," the world called it.

"Keep the public informed in order that hygiene may become part of its daily life," he said, "and lead to right living. Then by the end of the twentieth century," he prophesied, "we shall know what we ought to eat and drink to prolong our lives to that blessed day when death is a welcome visitor."

Although Metchnikoff milk is not the secret of long life, it may be that proper food is.

At this very moment, there are students working on the science of foods. Already we know that there are foods which strengthen cell life and foods which do not, and we have unraveled mysteries that long were a puzzle: why, for instance, scurvy attacks men at sea; why millions have died of the strange Oriental malady, beriberi; how a growing child's limbs can be made firm and healthy.

"Why does the germ of beriberi elude us?" scientists wondered, for all their efforts to find a germ had failed.

They noticed that only in tropical and semi-tropical countries — in China, Japan, Malaysia, and India — did beriberi claim its millions.

"Perhaps a germ isn't responsible for it at all," several suspected. "The food one eats may have something to do with it. Let us see. Now the people here in Japan, for instance, use rice instead of bread. Does rice then cause

beriberi? Somehow one kind of rice does and another does not."

Gradually the truth dawned upon a Dutch physician. "It's only polished rice that causes beriberi," he said, "rice with the skin removed. The tiny skin around each rice seed must contain some substance that one needs to be health."

Vitamin B we now call it, and find it in our vegetables, our fruits, and in the liver and kidney of animals.

"Have some celery! It is good for you," says your mother. For foods like tomatoes, celery, oranges, and grapefruit, contain another substance — Vitamin C. This protects us from scurvy and rickets; no growing child should do without it.

So far, at least six vitamins have been discovered, each one necessary to life. What other benefits the science of foods has in store for us, no one knows. Maybe by the end of the present century, the dreamer's prophecy will come true.

Metchnikoff himself, who drank quantities of his milk, lived to be seventy-one. He considered this a long enough life for him, because he had outlived all his family and because he had come to the point where death was a welcome thought.

His day's work was done, and he wished rest.

CHARLES ROBERT DARWIN

(1809–1882)

The Revolution in Biology

I

On a mountain peak in Tierra del Fuego, a wild and uncivilized portion of the earth, stood a young man, keenly observing. Snow was falling thick upon him from a misty sky.

Through the white net of the trees he glimpsed a lake upon which a canoe was gliding to shore. In it sat three natives who, despite the intense cold, were stark naked. The poor wretches were stunted in growth, and their hideous faces streaked with paint. Their skins were filthy and greasy, their voices sharp and croaking, and their gestures violent.

The young Englishman knew they were cannibals. He had been told that in the winter, when such cannibals are pressed for food, they kill and devour their old women. They have dogs, but these they never kill. Dogs are useful in hunting; old women, not.

He was musing on what strange sights this new world was showing him — a life so different from that of his native England.

Here was a country as large as Scotland, with a variety of plants, yet a small number of beetles. The few he found were living under stones. Here was a vast land, with no crickets, with few flies, butterflies, or bees.

In this strange land, he had found under the stones a

sea slug. He had looked for weeks for this kind and had found only seven of them. Yet he had come across its eggs, and when he had counted them, there were over two hundred thousand of them! And of these myriads, few developed. Life is a struggle!

On a mountain peak in Tierra del Fuego stood a young man.

Only a few weeks before, in the tangle of wilderness of the Falkland Islands, he remembered seeing a strange animal, half fox, half wolf, with gleaming eyes. "Can it be a fox?" thought he excitedly. "I have never seen one so large. A wolf? Then why the foxlike legs?"

But he was interrupted in his thoughts by the sight of a steamer duck. How strange! Here is a bird which uses its wings as paddles — a bird which feeds entirely on shellfish from the rocks. That must be why its beak and head are heavy and strong, so strong that they can scarcely be broken with a hammer.

The clangor of a bell just then rang through the air.

"Ah, our ship is about to leave. Captain FitzRoy is calling me back."

He began his descent.

"How strange!" he puzzled. "Why should so few sea slugs develop when millions of eggs abound? And if that wolflike fox had been less tall, or if that steamer bird's beak had been weaker, could they have survived? What happens to the weaklings?"

II

His father would have been proud of him indeed had he known his deep thoughts.

"You care for nothing but shooting, dogs, and catching rats, and you will be a disgrace to yourself and all your family," Doctor Darwin lectured his son Charles, for his school career at Shrewsbury had been a failure.

Later when his father sent him to Edinburgh University to study medicine — for Doctor Darwin did hope that his son would make a successful physician — he only stayed two sessions. There, too, he was a failure. He could not stand the sight of blood.

And Doctor Darwin disapproved of the way his son would spend his time tramping through fields or collecting insects; so he decided that Charles should become a clergyman.

But Charles was much more interested in collecting beetles than in his studies. As an amateur collector he was at times over-zealous. One day, for instance, on tearing off some old bark from a tree, he saw two rare beetles. He seized one in each hand. Just then he saw a third and new one. He could not bear to lose this one, so he popped the one which he held in his right hand into his mouth. The beetle ejected some intensely bitter fluid, which burnt Darwin's tongue, so that he was forced to spit the beetle

out, thus losing both this one and the third one, which he had not picked up.

Once coming home from a short trip to Wales, he found a letter, saying that the British government was about to send a ship around the world on a surveying tour, to map the coasts of South America and Australia. A volunteer naturalist was needed to collect specimens of animals and plants in those far-off wild portions of the earth. For his services he would get free board and passage.

Darwin, to his amazement, was recommended as the person best-qualified. The voyage was to last two years, and the letter said, "If you take plenty of books with you, anything you please may be done . . . Don't put on any modest doubts, for you are the very man."

Instantly he was eager to go on this adventure. He knew he could fulfill the scientific duties. He, therefore, went to his father to ask permission. His father shook his head. He frowned at this plan which would interfere with his son's becoming a clergyman.

But fortunately for Charles Darwin — and for the world, too — his father added, as an afterthought, "If you can find any man of common sense who advises you to go, I will give my consent." All hope seemed gone, for what man of common sense would approve of a two years' trip as a naturalist for one who was to become a clergyman?

So Charles sorrowfully wrote that although he would "most certainly, most gladly accept the opportunity", yet he must refuse the offer.

The following day, he happened to visit his uncle, Josiah Wedgwood. When his uncle heard about the offer, he thought tht it would be wise for Charles to accept, probably because he thought secretly that since Charles would not make a good clergyman or doctor, he could not be worse off as a naturalist.

Doctor Darwin had always maintained that Uncle

Josiah was one of the most sensible men in the world. He therefore felt that he had to keep his word; so he consented to let Charles go. Yet Charles narrowly escaped being rejected after all, for Captain FitzRoy did not like the shape of his nose. On talking with him further, however, the captain began to like young Darwin. In fact, he liked him so well that he shared his cabin with him.

On December 27, 1831, the *Beagle* sailed from Plymouth, England, to circumnavigate the globe. In its quiet way, this circumnavigation of the world was as epoch making as Magellan's. Instead of a two years' cruise, it was nearly five years before Charles Darwin again set foot in England.

III

"The misery I endure from sea sickness is far beyond what I ever guessed at," Charles Darwin wrote to his father shortly after he sailed. Nor did he ever improve much as a sailor. Yet he felt that the voyage on the *Beagle* was worth all his squeamish suffering.

No wonder! An ordinary traveler would never have noticed what his sharp eyes saw. In the Cape Verde Islands, for instance, there was the kingfisher. For hours Darwin watched the graceful bird, with his blue-green back and rich brown breast, nesting peacefully in the wintry waters. The halcyon, the Greeks called him, and they spoke of peaceful days as halcyon days. A king of fishers he certainly was. How he hovered over the black waves with his sure sense of a prey hidden beneath it! Darwin marveled. Like a hawk the bird hovered. Then suddenly, plunging headlong into the wave, he rose a moment after, the prey in his beak. Kingfisher, indeed!

In the same volcanic islands, an octopus, or cuttlefish, fascinated him. "They're so hard to catch," he thought, "darting as they do, tail first! And the way they can change

their color!" In deep water, the cuttlefish is brownish purple. Put it on land or in shallow water, and its dark tint becomes yellowish green. Look more closely, and on it you see bright yellow spots which disappear and reappear by turns. Scratch its skin, if he gives you the chance, and that spot becomes black. And those eight arms look dangerous. It would never do to meet the octopus face to face — if he has a face.

One day Darwin was watching his neighbor, the octopus, very closely. "How amusing," he thought, "that though he seems fully aware of me, he is trying to escape detection!" The cuttlefish remained still and motionless for a time. Stealthily it advanced an inch or two, like a cat after a mouse; now and then changing its color.

Suddenly a jet of water showered the face of Darwin. The cuttlefish had spurted water at him from a syphon on the under side of its body. Then, darting away, it left a dusky train of ink to hide the hole into which it had crawled.

Later the *Beagle* stopped at St. Paul's Rocks, off the coast of Brazil. Barren rocks they turned out to be, without a single shrub or plant of any kind. But to the keen-eyed Darwin they were places of excitement, teeming with life, small brown moths, beetles, a kind of wood louse, and spiders being of especial interest. And Darwin watched a crab, a gallant fellow, capture a flying fish . . .

Bright grasses, luxuriant plants, and new flowers made the first day he wandered in a Brazilian forest one of the most thrilling days of his life. In those same forests he experienced the weirdest mixture of sound and silence: noise of insects so loud that he heard them plainly even on the *Beagle* anchored several hundred yards from the shore, but if he stepped into the recesses of the forest, he was met by a profound silence.

To journey through Brazilian country was indeed an ad-

venture. He never knew when he would have to sleep under the stars. And oh, those inns! When Darwin and his men did see one on the road, they at least hoped to get food there. In the courtyard they would unsaddle their horses. Then with a low bow, they would ask the host if he could prepare a meal for them.

"Anything you choose, sir," was the usual reply.

Their mouths watered.

"Any fish can you do us the favor of giving?"

"Oh, no, sir."

"Any soup?"

"No, sir."

"Any bread?"

"Oh, no, sir."

"Any dried meat?"

"Oh, no, sir."

After waiting a few hours, Darwin timidly asked whether or not they had much longer to wait for their meal.

"It will be ready when it is ready," was the reply.

And there the matter rested. Just dare remonstrate, no matter how mildly, and you would be told to be on your way.

"It is snowing butterflies!" was the cry on board the *Beagle* one day.

Darwin rushed on deck to join the amazed crew. Millions of butterflies filled the sky, as far as the eye could reach. Even with a telescope, he could not find a space free from the fluttering things. The sun could barely peep through them. In his already full notebook, Darwin wrote about those butterflies, as the *Beagle* sailed on for the bleak Tierra del Fuego, with its cannibals and its condors wheeling about searching for carrion.

Darwin studied those black vultures as they sailed above, with never a flap of their wings. Vicious flying villains they were, Darwin learned. At dusk they wake from a heavy

slumber and fare forth from their roost on a high peak. They are out for supper. A calf or so apiece will do. In a pinch a sheep will answer, or when times are hard, a dog.

Then came the majestic Andes and the sight of a live volcano. Darwin was awed not only by a spitting volcano. He felt the shock of having the solid earth suddenly rock under his feet in one of the severest earthquakes Chile has ever experienced.

The Galapagos Islands with their dead craters and black lava were his next adventure. From these strange islands, whose only inhabitants are giant turtles, lizards, beetles, snakes, and birds, the *Beagle* sailed to coral islands in the Pacific, to Australia, and back to Brazil.

Not only for what Darwin's inquisitive eyes noted, but for the great idea that grew from his observations, this trip around the world has meant much to mankind.

IV

"Why should not the South American coast be littered with sea slugs when Nature is so lavish with the slug's eggs? And why should the steamer duck's beak and the wolflike fox be so big?" again thought Charles Darwin.

At his home in England for years this question lured him. The thousands of specimens of plants, animals, and rocks he had brought back from his voyage were his constant care and study.

Years passed. In a book one day, the following sentences attracted his attention: "If it were not for disease, war, and famine, population would increase so fast that there would not be enough food for all . . . Life is a struggle."

He laid the book aside, wrinkling his brow. "But why are some animals lucky enough to win in the struggle for life, while others lose out and perish?" was the protest that

flashed from his mind. Oddly the answer at once occurred to him, "Those that survive are more fit to win."

If the struggle of life were a football game, then only those who had powerful legs, a good eye, and a light body would win and survive. And a football coach, choosing a team, selects only that kind. Nature is like that football coach. She selects only those who have the traits which can conquer.

The young naturalist knew he was on a new trail. It was a big moment in science. He thought on enthusiastically: "I have it! Suppose two animals are taken to the frigid zone, one with fur, one without. The one without fur will die of cold and will not have offspring. The one with fur will survive the cold and have offspring. The children, like their parents, will have fur. Good. But how about that fox-like animal I saw in the Falkland Islands? Its thin legs? It must have thin legs to win out in the struggle for existence."

A pretty thought! But could he prove it true? Well, he could do no more than his best; he would try. Quietly he went to work, studying the life of animals and plants of all climates — quietly and cautiously, with no hullaballoo or boasting. He sat in his room, day after day, day after day, for twenty years. Almost too quietly, for only two other people knew what he was doing.

"Why don't you announce your idea to the world?" grumbled his friend Hooker. "Here you're working a lifetime, giving your life to prove this wonderful belief, and soon some youngster will come along, without proof, and make a good guess, and get all the credit for the theory."

His friend, Professor Lyell, agreed with Hooker. "You'll be robbed of all the glory," he warned gravely, "if you don't take a chance and stake your claim."

To these entreaties Darwin made modest answer, "I am a faithful servant of science," he said humbly. "And

I would rather have the satisfaction of knowing I was thorough and faithful than have the praise of the world."

And yet he knew that when the time came and his work was complete, his would be the glory. Heaven knew he deserved it! Twenty years of his life, with sickness every day so that he could work only a few hours a day! The only thing that cheered him on, the one thing that had invigorated his flagging health, was the thought that some day, when he laid the fruits of his life at the feet of the world, it would say to him, "Well done, good and faithful servant. You have shown us the way. Your life has not been in vain."

That day would come to him. But first he must be sure of the truth. He would make haste slowly. Just a little longer — there were just a few more experiments to study, a few more specimens to examine. He was almost ready to prove the theory he had whispered to his friends, Lyell and Hooker, twenty years before. He had kept the secret for twenty years because he would give the world nothing to retract. But now it was almost all done, his work — almost . . .

A bolt shattered his heaven! It struck Darwin a blow that would have prostrated a less courageous man. His life seemed bitterly wasted. A young Englishman, Alfred Russell Wallace, cruising in the Indian Ocean, had thought as Darwin had twenty years before and had had the reckless enthusiasm to write down his idea.

Not knowing that Darwin had been the first to have the thought, Wallace sent the manuscript to him. He asked Darwin to announce it to the world for him.

"My dream of twenty years is over," throbbed in Darwin's brain. "The glory and pride of being the first is not mine. Silent for twenty years, I must now remain silent forever."

And then he made a sacrifice, which places him among

the greatest heroes. Without a word for himself, without a quiver, he sent the manuscript to his friend Lyell.

"Your words have come true with a vengeance," Darwin said mournfully to the astounded Lyell. "My hope for glory is over . . . Well, I hope you will approve of Wallace's sketch."

This showed that he renounced first claim to the discovery.

When Lyell and Hooker had recovered from the first shock, they protested vehemently. "What! Throw away your claim to immortality, when we can testify that you had the theory while this Wallace was a schoolboy! No! Let's explain to this fellow Wallace."

But Alfred Wallace could be as generous as Darwin. "Of course you deserve all the credit," he said heartily. "I feel proud that I have ever been able to think your thought. That you had the idea of natural selection long before I did, of that I am convinced, my master."

The world will not soon forget these two generous souls. The sacrifice they could make for the cause of science, they were ready to make for each other.

Charles Darwin received his immortality — greater than he had hoped for in his most ambitious moments. Darwin's work has been the guiding light to all biologists, for it has revealed why living things become what they are. The gallant Wallace has his share, also. Side by side with Darwin he stands in the discovery.

GREGOR JOHANN MENDEL

(1822–1884)

The Modest Monk

I

THE whole world was in a pitch of excitement over Charles Darwin's discovery of the reason for so many different kinds of animals.

"Animals need various kinds of limbs, sizes, and shapes," Darwin had said simply, "because of the various climates and places in which they have to get their living."

"Yes, we see that," some protested. "We see why the seal needs its fur if it's to live in the polar regions. We see why the tiger needs its strength if it's to live in the jungle. But how is it that these animals get what they need? How does the seal come by its fur, the tiger by its agility?"

The world grew noisy over the question. In the midst of this excitement, no one noticed Gregor Johann Mendel. Since he was not the kind who rushed about, singing his own praises, he remained unnoticed until recently. To-day a man is proud to be able to say he is on speaking terms with the Mendelian Law.

Gregor Mendel's interest in science began when he was yet a boy. Two of his chums had just come back from school for the holidays. When they told him what they studied, they so excited his interest that he begged his parents for permission to study, too. This, however, meant a great sacrifice for his father, who owned only a small farm. Nevertheless, he sent Gregor, who was only eleven, to

school. Here young Mendel so distinguished himself that his parents decided to deny themselves the comforts of life to continue his education.

As a young man, Mendel became a teacher of science in the town of Brünn, in Bohemia, and a monk in the monastery there. In the garden of the monastery was a large bed of plants about which everybody was curious but which nobody dared touch.

"This is Brother Mendel's bed of peas," visitors were told. "What he does with these peas we do not know. He does not eat them, yet he grows and grows them. For years he has been doing it."

For eight years he bred those peas. After that he did not need to breed them any longer, for he had found what he wanted . . .

"You resemble your father." Mendel had often heard that said. It was a simple enough thing to say, yet like a true scientist, he did not let the simplest statement slip by without considering it. He wanted reasons. He was a sentinel of learning, who challenged every saying, no matter how familiar.

"Why do some people resemble their father, other people their mother?" he wondered. Many men before Mendel had asked the same question, yet all their efforts to unravel the mystery had only complicated matters. A child might resemble his father in color of eye and in tone of voice, and yet in other ways remind friends of his mother or of his grandparents. How does heredity work? What does it hand on to posterity? In despair some learned men gave up the search.

"But why do some people have brown eyes, while other people have blue eyes? Here is a red-haired man. Neither his father nor mother is red-haired, but his grandfather is. How does heredity influence the matter?"

"There must be a reason," said Mendel. "Perhaps the explanation is difficult, and will take time and hard study to work it out. Scientists have not been patient enough. I shall try a different method. I shall study the garden pea."

It was a rather strange question to ask of a garden pea; and stranger still that this simple vegetable should answer. Its success lay in the way the question was put, and this is how Mendel put it: "What would happen if I

It was a strange question to ask of a garden pea.

crossed a tall plant with a short one? If I can find out how the offspring of the pea resembles its ancestors, perhaps then we shall be ready to understand why man is as he is — and not till then. I shall study one trait of the pea at a time."

He knew that, left to themselves, tall plants produce seeds which bring forth tall plants, and short plants bring forth shorts. But suppose he crossed a short with a tall?

He did. He took pollen from the flower of a short plant, not more than two feet high, and scattered it in the flower of a tall one, about six feet high.

A striking result followed. Every one of the offspring of this marriage was tall.

"Tallness," Mendel wrote in his notebook, "must be a *dominant* trait. It dominates over shortness." Of course, Mendel did not let the matter rest there. He kept on experimenting with those peas. He let the tall children alone, until they, too, formed ripe seeds. These he sowed. New plants grew — you might call these the grandchildren of the first ones which he studied.

What happened now was remarkable. These grandchildren were not all tall. One out of every four was short!

"Shortness," Mendel wrote in his notebook, "does not appear until the second generation. It is a *recessive* trait. And even then only one out of every four plants is short."

He now suspected that some traits of human beings, like tallness or the color of eyes, are inherited in the same way. But he was cautious. He continued growing the peas.

When he sowed the seeds of these groups of four plants, a yet more remarkable thing came to light: the short plant of each group had nothing but short offspring; and one tall plant had nothing but tall offspring; but the other two tall plants gave a mixture of three tall plants to one short one.

On and on he sowed and reaped his peas. And always he got the same results: of every four plants, there were three talls and one short; the short bred short plants; one tall bred only tall plants; and the other two tall plants gave a mixture of three talls to one short.

Patiently he worked on. He had discovered one quality of the pea that is inherited — height.

"What other traits are transmitted? From now on I shall study how the flowers arrange themselves on the stem. I

know that in some plants the flowers form along the axis of the plant, while in others they are bunched together at the top. Is this a question of inheritance, or is it just an accident?"

Notebook in hand, Mendel watched the garden peas flower, and his sharp eyes noted the position of every blossom. With great satisfaction, he saw that the same principle he had discovered about height worked here. The flowers ranged on the axis on the stem had the dominant trait. Surely there was method in Nature.

Another person would now have told the world about his great discovery. Not so Mendel. He said to himself, "If what I have discovered is a law of Nature, it must prevail in more than two qualities. I must find many more traits that are inherited in the same way before I let the world know about my garden peas." He now studied the color of the pod while still unripe. A shade of green was the *dominant* quality, while only one out of four pods was bright yellow. Here was another example of *dominance* and *recession.*

"How about the shape of the seeds? Some peas are rounded and others wrinkled. Do these follow the same rule, or is their shape governed by chance?"

Mendel's experiments were so careful — he grew more than ten thousand plants before he felt sure he was right — that we owe a new science to him. It is the science of breeding and growing, genetics, and its laws are the ones Gregor Mendel discovered as he raked and hoed and tended the bed of peas in his little garden.

It was an amazing discovery, and people began by shrugging and saying, "What does it amount to, this discovery? It concerns the raising of peas, perhaps, or even all plants. But there remains the world of animals and human beings whose physical appearance is still a mystery."

The doubters were mistaken. The cattle raisers were able to come forward and say delightedly, "Mendel has confirmed our own experience. For instance, when we mate a horned animal with a hornless one, the offspring are mostly hornless — three hornless to one horned one. The horns tend to disappear — they are a recessive trait."

All over the world biologists began to test Mendel's theory. All sorts of animals as well as plants were raised, and with each new experiment the name of Gregor Mendel was used with greater authority.

"Who is this Mendel?" people began to wonder. "Who is he that has discovered this new law of Nature?"

But Mendel was dead, and the fame which had passed him by when he was a monk in Brünn could now honor only his memory.

II

Mendel and Darwin, in addition to satisfying our minds, have also provided for the comfort of our bodies. Luther Burbank, a lad in Massachusetts, saw that possibility with the insight of genius. He was reading a book by Charles Darwin.

"Look sharply," the naturalist had written, "and you will notice that no two daisies are alike, nor any two roses. They vary slightly in size, in color, in shape."

"Why?" thought Luther Burbank.

And he learned from Darwin — he did not yet know of Mendel — that in this manner plants gradually changed.

"Put two goldenrods in the same cool climate," were Darwin's further words. "Watch closely and you will see that only the hardier of the two flourishes."

"Darwin is perfectly right," thought the boy. "The plant *must* adapt itself or die. That is the reason it changes — to fit in better with its surroundings."

Then a wonderful idea came to him, an idea that was to guide his life and become a blessing to humanity.

"If Darwin *is* right, I can grow plants to order. Suppose we want a grain of wheat that is larger than the one we usually have. In the wheat field, Darwin assures us, we will find some grains that are slightly larger than the rest. Let us plant the seeds of these larger grains only. Then from the new crop, we will plant only the largest seeds again. And so on. Soon we ought to have much better wheat for our bread."

He saw before him his career — to put the world of plants to greater use than ever before. He would grow grapes sweeter and larger than any one had ever eaten, plums without pits, oranges without seeds, potatoes so large that a single one would make an ample meal for some hungry person . . .

In the fertile soil of California, Burbank worked hard on his strange scheme to improve the gifts of Nature. If in Nature's garden he found two plums, one large but not sweet, the other sweet but small, he would think, "We must have a fruit that has the size of this one and the sweetness of that." He would cross the two plants, and as Mendel showed, some of the offspring had to be large and sweet. These the happy Burbank kept and cultivated season after season. The result was that when the housewife went to market one day, she exclaimed, "What beautiful, large plums! And so sweet! I have never had such fine fruit." Did she ever think of Burbank, reading his books and making his lifelong experiments? Or of Charles Darwin? Gregor Mendel was probably not even a name to her.

The "plant wizard", as the world dubbed Luther Burbank, raised over a million plants every year. His success was so uncanny that it was jokingly said he could grow omelettes by crossing eggplant with milkweed. He did

something which was almost as unbelievable when he raised a spineless, edible cactus.

No plant was too insignificant for him to improve. Once he was walking along and noticed common daisies lining the edges of the road.

"Oxeye," he murmured. "If you were larger, whiter, and had a tall graceful stem, you might become the queen of flowers." To a listener it would have sounded like the fantastic talk of a poet. How could a vicious weed change into a beautiful flower, with petals of the purest white, on a slender firm stem?

Burbank found that in England there grew a large daisy. It was merely a coarse weed, a stalk covered with unsightly leaves. He sent for it, and with it, crossed his own daisy.

"I shall combine the best qualities of both," he planned. The following season he had an assortment of daisies growing in his patch — some with large, others with small, petals; some coarse and weedy, others of a nobler bearing. From the prize flowers he selected his seeds and sowed them for the next season. Six years of careful choosing, and he had what his gardeners called a perfect flower. But Burbank was not satisfied. Only his eyes could detect that yellowish tinge to the petal. No, his flower must be as white as the snow on a mountain peak.

"I must find a white daisy somewhere," he persisted, "even if it grows on the other side of the globe."

There it was indeed, on the other side of the globe, in Japan. It was coarse. It had a poor stalk. Its flower was small. But it had the one feature that Burbank wanted; its petals were pure white.

Now it was only a matter of time and of the Mendelian law before his wonderful daisy appeared at last. Its blossom is remarkable for its beauty; a brilliant white with a center of gold, its stem gracefully tall, and bearing no un-

lovely leaves. Nor is its beauty of the clinging, weak kind. It can thrive anywhere from Alaska to Patagonia and blooms the very first season it is planted.

"Be ye called," said Burbank, "the Shasta Daisy, after Mount Shasta, for you rival the whiteness of its dazzling snowcap."

III

Not so many years ago, when Russia was still ruled by a Czar, great anxiety reigned in the court there. The Czarevitch was suffering from a mysterious complaint. Painlessly and for no apparent reason, blood would begin to flow from his nostrils and would stop only after it had exhausted the child.

"Where did he contract this disease?" the royal family asked the court physician.

The eminent doctor shook his head. "He did not contract it," he pronounced. "He has inherited it."

"But neither the Czar nor Her Majesty has it."

"Of course not. The disease skips a generation. It follows the Mendelian law for recessive traits — the law which excepts no royalty."

For all those traits that parents transmit to children follow the rule that Mendel discovered in his garden patch of peas. The knowledge that we owe our appearance and the traits of our characters to our parents and grandparents; the knowledge that underlies our whole science of breeding and growing — the science on which much of our food depends; and our understanding of certain diseases: this is our eternal debt to Gregor Johann Mendel.

Our heroes, we see, are great fighters, as we said they should be. Their weapons are not brute force and fear, but reason and understanding. Their battlefield is a study or laboratory. The enemy is no human being. It is Ignorance, and against this common enemy, all the fighters pit themselves bravely.

When one fighter wins, everybody wins; the whole world, now and to come, wins. For if to-day we engage passage on a boat, do we not share in Fulton's victory a hundred fifty years ago? And is it not Lister's voice that helps to instruct our own surgeons how to save our lives?

Heroes, with the glory of such lasting victories, bid us follow them.

PUPIL ACTIVITIES

NICHOLAS COPERNICUS

(Page 3)

I. You will find it important to know the following *key words:*

astronomy	planet
astrology	star
constellation	solar system

superstition

II. If you have read this chapter carefully, you will be able to supply the missing words below:

Copernicus was born in the country of ________ in the year of ________. He was educated at the University of ________, and then went to ________, where he studied ________, ________, ________, and ________. He was expert as a ________, and successful in the career of ________. He wrote a book on ________. His chief interest, however, lay in ________. But in this study he was handicapped by lack of a ________.

After much study of Ptolemy's book and after his own observation of the heavens, he decided that Ptolemy was wrong. The center of the universe was not the ________. He proved this by ________. He also proved that the earth revolves around the ________, and so he explained ________ and ________. He may justly be called the first great modern ________.

III. Below at the right, in irregular order, are the scientific names (in Latin) for the constellations listed at the left. Can you choose correctly the scientific name for each constellation? Use your dictionaries or other reference books.

1. Great Bear	Cygnus
2. Lion	Canis Major
3. Swan	Canis Minor
4. Little Bear	Ursa Major
5. Great Dog	Taurus
6. Bull	Ursa Minor
7. Ram	Leo
8. Little Dog	Aries

IV. The following interesting facts can be made complete by supplying one word for each blank. You are allowed to use an encyclopedia or any other reference book:

1. The modern astronomer uses mathematics, photography, and the telescope. Copernicus could use only one of these. He used ________.
2. Therefore, Copernicus could not know that the distance from the sun to the earth was ________ miles.
3. Nor was he aware that the size of the sun was more than a ________ times that of the earth.
4. Ptolemy's tables were unable to predict accurately certain astronomical events. The modern astronomer can predict ________, ________ of ________, and their ________.
5. While Copernicus was changing the map of the heavens, the following explorers were changing the map of the earth: ________, ________, and ________.

V. Tell which of the following quotations from Shakespeare refers to astrology and which to astronomy:

1. " . . . It is the stars,
   The stars above us, govern our conditions."
2. "The fault, dear Brutus, is not in our stars,
   But in ourselves, that we are underlings."
3. "But I am constant as the northern star."

VI. Special Problem:

The following is an extract of a letter written at the time of Copernicus by some one who opposed him. How would you defend Copernicus?

"It is proved that the heavens are moved and the earth is stationary: First, by authority, for this is asserted by Aristotle and Ptolemy. Second, it is proved by reason: All the heavens and stars were made in man's behalf and are servants of man . . . man is not their servant. Therefore, it is more probable that the heavens are moved and the earth is at rest."

GALILEO GALILEI

(Page 12)

I. Complete the following summary by supplying a word for each space.

Galileo Galilei was born in ________, Italy, in the year ________. As a youth he distinguished himself by his talent for ________, ________, and ________. He decided, however, to study ________ and ________.

When Galileo was eighteen years old, he invented the ________. One of his greatest experiments was his test whether a heavier body falls faster than a ________ one. He dropped two weights from the leaning tower of ________. In this way he proved that the Aristotelians were ________.

Galileo once heard that an optician in Holland had held two lenses in such a way that objects appeared through them ________ but ________ ________. On the next day, Galileo made a ________, better than the optician's. An object appeared through it ________ and ________. With the telescope he discovered ________ on the moon, and ________ on the sun. He saw that the Milky Way consists of ________ of ________. In 1610 he discovered four ________ of Jupiter. And he also proved that the theory of ________ is correct. Galileo died in the year ________.

II. Key Words:

sector	pulse
telescope	dynamics
pendulum	satellite

III. With the help of an encyclopedia, find the words necessary to complete these sentences.

1. The theory that the earth revolves around the sun was announced by ________.
Galileo was able to prove this theory by developing the instrument we call a ________.
By means of this instrument he showed that there were ________ on the sun.
The changing position of these proved that the sun, like the earth, ________.
He also showed that on the moon there were ________.
2. The moon is a satellite of the ________.
The earth is a satellite of the ________.
There are satellites also about the planets ________ and ________.
3. Aristotle was a ________ who lived in ________ in the ________ century.
John Milton was a ________ who lived in ________ in the ________ century. His most famous work was ________.

IV. Special Problems:

1. Why was Galileo called the founder of the science of dynamics?
2. Locate on the map of Italy the towns in which Galileo lived: Pisa, Padua, Venice, Florence, Rome.
3. A contemporary scholar of Galileo, when he heard of "spots on the sun," immediately referred to Aristotle's writings and, not finding any sun spots there mentioned, held that Galileo was wrong.

What answer would you give to this proof?

4. Galileo, sometimes called the "father of experimental science" because he trusted nobody's word, teaches that ice, because it floats on water, is rarefied water and therefore lighter than water.

Don't trust Galileo in this. Put him to the test, and when you have performed the experiment, tell whether Galileo is right.

CHRISTIAN HUYGENS

(PAGE 22)

I. Key Words:

hourglass
pendulum
vibration
light wave
nebula
optics

II. Supply one word for each blank below:

Christian Huygens was a native of ________, born in the year of ________. From early youth, like the astronomer ________, he was chiefly interested in ________. Like him, too, he found that the problem of the ________ had to be solved before he could continue with his study of astronomy. Huygens succeeded not only in solving the problem which had worried astronomers before him, but also perfected the ________ so that now he was able to measure the distances on the stars. As a result he discovered that the planet ________ had ________. By means of his powerful ________ he also discovered ________ in the constellation Orion. His studies in astronomy and mathematics naturally led to further discoveries. These he wrote in his book called "________ ________ ________ ________." He finally became absorbed in the study of the behavior of light, and worked out the new science of ________. His ________ of light was perhaps his greatest achievement. He died June 8, ________.

III. In ancient days people told time by four different means. State what they were.

IV. Strangely enough, to-day a modification of one of these is used in the kitchen. Which one? In the garden. Which one?

V. Huygens made improvements in the telescope in regard to its ________ and ________. By means of the latter, he was able to judge ________ on the stars. By means of the former, Huygens saw clearly [what Galileo could not] the planet Saturn, and discovered its ________. He also was able to see ________.

VI. By the use of his accurate clock and improved telescope, Huygens was able to determine that the planet Mercury is three times nearer the sun than is the earth.

Make a list of the planets in the order of their distance from the sun.

VII. Our earth has one moon.

Jupiter has ________ moons.

What other planet has as many moons as Jupiter?

SIR ISAAC NEWTON

(PAGE 31)

I. Key Words:

ellipse
circumference
lenses
prism
spectrum
inertia
gravitation
orbit

II. Complete this summary by supplying words for the blanks:

1. The earth's circumference is ______ miles.
2. Its orbit around the sun is in the form of an ______.
3. This form is determined by the force called ______.
4. Isaac Newton was able to measure this force by inventing a mathematics called ______.
5. Using Newton's Law of Gravitation, astronomers discovered the planet ______.
6. Newton, like ______ before him, studied the question: What is light? As a result Newton discovered that light is made up of the following primary colors: green, red, yellow, orange, blue, indigo, violet.
7. These colors are usually known as the colors of the ______.
8. Arrange these colors in the order in which they always appear.
9. Newton's discoveries and calculations were published by his friend, the astronomer, ______, in a book called ______.

III. Problems:

1. Find the exact statement of Newton's "Law of Universal Gravitation."
2. How does this law explain: (1) high and low tide? (2) weight of a body? (3) why people do not fall off the revolving earth?
3. How does a rainbow prove Newton's discovery of the make-up of light?
4. Where is the largest telescope in the world located? Give a few facts about it.

ANTOINE LAURENT LAVOISIER

(PAGE 42)

I. Key Words:

chemistry	hydrogen
experiment	acid
oxygen	combustion
physiological	atmosphere

II. Complete this summary by supplying one word for each blank.

Antoine Laurent Lavoisier, a native of ______, in the year 17__ attended a lecture and demonstration which was to show why things burn. Like a true ______, Lavoisier was not content to accept the conclusions of others, but made his own ______. He therefore discovered that it is not fire particles, but a ______ in the air that make things burn. While experimenting with ______, he found that when the substance had burned away there was left an ______ in his dish. He accordingly named the gas in the air which causes combustion ______, from the Greek word meaning "______."

At this time an English chemist, named ______, made the discovery that there is a gas which burns. Lavoisier made this gas in his laboratory, and on adding ______ found that ______ was formed. So he called this gas ______ or "______ ______."

Lavoisier put the account of his ideas and experiments in chemistry in a ________ and earned for himself the title "________ ________ ________ ________ ________."

III. The statements in the left-hand column have their reasons, or "proofs," somewhere in the right-hand column. For each statement, choose its proper "proof."

1. Lavoisier is called the "founder of modern chemistry."	He showed that a glass of water weighs as much as its hydrogen plus its oxygen.
2. He made an important contribution to business.	He taught that we must weigh and measure carefully all the substances in an experiment.
3. He began the study of physiological chemistry.	He invented the metric and decimal systems.
4. He was interested in questions of social betterment.	He experimented with the chemistry of the human body.
5. Lavoisier was accurate and exact.	He established a model scientific farm; a bureau of life insurance; and believed in old age pensions.

IV. Problems:

The following names are associated with Lavoisier's: Priestley, Cavendish. Give an account of the work of one of them.

Lavoisier discovered the composition of water. With the help of an encyclopedia or science textbook find the composition of air.

JAMES WATT

(Page 52)

I. Key Words:

compass
sector
micrometer
condensation
compression
engine
quadrant

II. Supply one word for each of the following blanks:

Too frail for much besides study, James Watt spent his youth reading books on ________, ________, ________, and working in his father's ________ shop, where he succeeded in making an ________ machine. When James was ________ years of age, he went to ________ to earn his living. There he became apprentice to an ________ maker, and soon made excellent ________ and ________. A professor of science in the ________ of ________, impressed with Watt's work, offered him a room and urged him to make and sell ________. Here he was happy working and ________.

Because he was once asked to repair an ________, he learned the mechanism of all ________ instruments and built ________, ________, ________ and ________.

All machines interested Watt. When the Newcomen engine, propelled by ________, was in need of repair, he was consulted. He found that it was inefficient because it was too ________. For months he labored over the problem of overcoming this defect. At length he solved it, and built a new engine which did the work much ________. He received his patent on the ________ ________ on January 5, 17__, the same day that Sir Richard ________ received a patent on the ________ ________. The world's tribute to James Watt is expressed in a colossal statue of him in ________ ________.

III. James Watt was a versatile man.

Look up "versatile" in the dictionary, and, from what you know of Watt's character, prove this statement to be true.

IV. Complete the following sentences with as many words as are necessary.

The Newcomen engine was used only to ________ .

The Newcomen engine was improved by the introduction of a ______.

V. Since Watt's engine many steam-driven machines have been invented. What are three modern machines resulting from Watt's invention?

VI. Name three other inventions by Watt that are in use to-day.

VII. Problem:

The "watt" is a unit used in measuring electricity, named in honor of James Watt.

Define: 1. a watt; 2. a kilowatt; 3. a kilowatt-hour.

SIR HUMPHRY DAVY

(Page 60)

I. Key Words:

colliery
element
potassium
sodium
quicksilver
battery

II. Complete this summary by supplying words for the blanks:

1. Humphry Davy was known in England in the nineteenth century as the greatest living ________.
2. In 1815 the mine owners appealed to him to devise a means of saving the miners' ________.
3. Davy experimented with the malignant fire damp, and found that it exploded only when mixed with air that was ________ times its own amount and when the sides of the lamp were ________.
4. By making use of his knowledge of the gas, ________, Davy succeeded in making a ________, since used by the miners and known as the ________.
5. He solved the problem by keeping all but a little air out of his lamp, but admitting a little by small ________, because the flame needed some air in order to ________.

6. He prevented the sides of the lamp from overheating by using wire ________.
7. Because of his experiments with gases he discovered ________ ________, so useful in the practice of ________.
8. His experiments with currents of electricity led to the discovery of the ________ arc light.
9. Although not a rich man, Davy refused to ________ his discoveries, saying that his sole object was ________ ________ ________.

III. Complete each sentence begun in the left-hand column by choosing its proper ending from the right-hand column.

1. Mr. Buddle was	a great English poet.
2. Baronet was	a scientific name for laughing gas.
3. "Elements of Chemistry" is the title of	a poet laureate of England.
4. Dr. Beddoes	a mine owner at Bristol who sent for Davy.
5. A magnet is	a book by Lavoisier that Davy studied.
6. Samuel Taylor Coleridge was	a title conferred on Davy by the King of England.
7. Nitrous oxide is	made Davy superintendent of the hospital at Bristol.
8. Robert Southey was	a mineral that has the power of attracting bodies.

IV. Projects:

1. Find out who was awarded the Davy Medal in Chemistry last year.

MADAME MARIE SKLODOWSKA CURIE

(Page 70)

I. Key Words:

compound	crystals
nitrogen	electron
ore	proton

II. Complete the following summary by supplying words for the blanks:

Marie Sklodowska Curie was the daughter of a professor of ________ in ________. As a young girl she assisted her father in his ________ and later became a student of ________ herself. For further study she went to ________, where she suffered hardships because of her ________. Finally she got work as a ________ in the ________ of a professor in the University of ________. There she met Pierre Curie whom she later ________.

Inspired by her friend Röntgen to investigate the behavior of ________, she devoted all her time to it. Her husband, who had gained some fame for his work on ________, also was attracted to this strange discovery and joined her researches.

For their experiments they required a large amount of ________, the ore from which ________ was extracted. They appealed to the ________ government, which owned the largest mines, and were given a ________ of this mineral for experimental purposes. After many months they discovered that the element contained in the ore, after ________ had been extracted, gave off powerful ________. They named it ________, after Madame Curie's native country. After more research they found that the residue had still greater powers, an element whose rays consist of particles traveling almost with the speed of light, ________ miles per second. It was named ________.

Professor and Madame Curie were given the ________ Prize for Physics in 19___ and Madame Curie was appointed special lecturer at the ________ in ________. After the accidental death of her husband, Madame Curie continued her researches in the use of ________ and in 19___ was awarded the Nobel Prize for ________. She refused the suggestion to patent her discovery, preferring to give her work to humanity.

III. Complete each sentence begun in the left-hand column by choosing its proper ending from the right-hand column.

1. William Crookes	the ore from which uranium is taken.
2. Wilhelm Konrad Röntgen	the time needed for an ounce of radium to spend itself.
3. Pitchblende is	discovered X rays.
4. Radium is	first experimented with an electric current in a vacuum.
5. 100,000 years is	the residue when uranium has been extracted from pitchblende.
6. Lead	one of the colleges of the University of Paris.
7. The Sorbonne is	the mineral to which radium changes after giving off all its rays.
8. The Nobel Prize is	the element named after Madame Curie's native country.
9. Polonium is	a sum of money annually awarded to those achieving the best work in each of a group of fields.

IV. How is the X ray used by the (1) dentist (2) doctor (3) surgeon?

V. The name of Ernest Rutherford has also been connected with the study of substances giving off rays. With the help of the encyclopedia mention three important facts about him.

VI. The human body has senses which detect the presence of light and heat vibration, but our senses give us no indication of the presence of X rays. Prove this from the text.

VII. What other vibrations or waves are there in space that are used to-day?

ALBERT EINSTEIN

(PAGE 80)

I. Key Words:

molecule	physics	atom
calculus	eclipse	electron
algebra	relative	dimension

II. Supply the missing words for the blanks:

Albert Einstein, born in the town of ________ in 18___, was at an early age interested in the study of ________. He later went to the Zurich Polytechnic Institute, and though he wanted to be a ________, for a while he earned his living as a ________ in the ________ Patent Office. All his spare time, however, was devoted to the study of ________ and ________. At the age of ___ he astonished the world by solving one of the mysteries of the universe by means of his theory of ________. He also clarified the problem of the Brownian movements of ________, which had puzzled scientists for many years.

For his scientific achievements he has been honored everywhere, and in 1921 received the ________ Prize. Besides being a great scientist, he is also a fine ________, performing excellently on the ________ and the ________. In addition to all this, he still finds time to work for the outlawing of ________ and achieving world ________.

III. Choose the item in the parenthesis that will complete the sentence correctly.

1. Copernicus showed that the earth is (moving, stationary).
2. The experiments of Professors Michelson and Morley seemed to show that the earth is (moving, stationary).
3. Albert Einstein contends that the earth is (moving, stationary, both moving and stationary).

Can you explain Einstein's reason for this answer?

IV. Consider the "relativity" of Mr. John Jones:

1. Mr. John Jones is a ________ to Mrs. John Jones.
2. Mr. John Jones is a ________ to Johnny Jones, Jr.
3. Mr. John Jones is a ________ to Johnny's grandfather.

V. Choose a word within the parenthesis to complete the sentence correctly.

1. (high, low) The Empire State Building in New York is ______ compared to a two-story house.
The Empire State Building in New York is ______ compared to Mt. Everest.
2. (bright, dim) The electric bulb is ________ compared to a candle.
The electric bulb is ________ compared to the sun.
3. (far, near) The North Pole is ________ to the Mexican.
The North Pole is ________ to the Greenlander.
4. (rises, sets) The sun ________ in New York at the same time that it ________ in China.

5. (above, below) The person on the balcony is ________ the street.
The person on the balcony is ________ the roof of the same house.

VI. Three trains leave New York on parallel tracks: the first goes at the rate of 30 miles per hour; the second goes at the rate of 40 miles per hour; the third goes at the rate of 50 miles per hour. The engineer on the first train observes that the third train passes him at the rate of ________ miles per hour. The engineer on the second train, however, observes that the third train passes him at the rate of ________ per hour. At what rate does the third train pass a telegraph operator located in a railroad station?

V. Consult the encyclopedia for a biography of Albert Michelson.

WILLIAM HARVEY

(Page 93)

I. Key Words:

physiology	gland
artery	carbon dioxide
vein	corpuscle
capillary	valve

circulation

II. Choose words necessary to complete the following statements:

1. William Harvey was born in England in 15__.
2. He first announced to the Royal College of Physicians in ________ that the blood ________ through the body.
3. He established the following facts:
   (a) The blood is kept flowing in one direction by means of the ________.
   (b) The tubes which carry the blood away from the heart are ________.
   (c) The tubes which carry the blood back to the heart are ________.
   (d) Tiny tubes connecting the former and the latter tubes are called ________.
   (e) The constant pumping of the heart can be heard and is called the ________.
   (f) Halfway through the heart the blood goes from the heart to the ________.
   (g) Here it receives ________ which makes the color ________.
   (h) The blood carries to the body cells ________.
   (i) The blood receives from the body cells ________, making the color ________.
   (j) The blood gets rid of cell wastes by means of the ________.
   (k) The blood then enters the heart through the ________ side.
   (l) The blood leaves the heart through the ________ side.

4. Harvey published his findings in a book called ______.
5. While in attendance on King ______, many of his writings were destroyed in a raid on his house.
6. His published work, however, furthered the science of ______.
7. He died in 16___.

ANTON VAN LEEUWENHOEK
(Page 102)

I. Key Words:

animalcule
protozoön
amoeba
bacteria
generation
spontaneous

II. Complete the following summary by supplying words for the blanks:

Anton van Leeuwenhoek was a native of ______ where he made his living as a ______. His real interest, however, was in grinding ______. The microscopes that he made were so powerful as to magnify objects ______ times. He made ______ of these microscopes, as well as ______ lenses. Through these he peered at ______ and ______, and discovered a world of one ______ beings, thus disproving Aristotle's theory of ______ generation. These unicellular animals are called ______. By constant observation of these under all conditions he found that they were carried through the air by particles of ______. In addition to these animals, Leeuwenhoek also discovered one-celled plants which are called ______. Although Leeuwenhoek saw everything through his powerful ______, yet he did not know the purpose which these living ______ served.

He wrote about his discoveries in two letters to the Royal Society, and thus gave to the world a new body of science.

III. Complete each sentence begun in the left-hand column by choosing its proper ending from the right-hand column.

1. Yeast is	the study of animal life.
2. Bacteriology is	a friend of Leeuwenhoek.
3. An aeon is	the world of first life.
4. Hoogvliet was	a common plant of one-cell structure.
5. Zoölogy is	the study of plant life.
6. Protozoa are	the birthplace of Leeuwenhoek.
7. Delft is	the czar of Russia.
8. Peter the Great was	organisms (animal or plant) that live on other organisms.
9. Parasite	an immeasurable period of time, many ages.

EDWARD JENNER

(PAGE 111)

I. Key Words:

smallpox	inoculate
epidemic	contagious
vaccine	quarantine
pustules	cowpox

II. Complete the following summary by filling in the blanks:

Edward Jenner liked to study ________ and ________ and tend the ________. He was also a talented ________.

It is as a doctor, however, that Jenner is now chiefly remembered, for it was in this capacity that he discovered the ________ against ________. He noticed that there was a connection between ________ and smallpox. Although the former is a mild disease, when incurred by human beings, it makes one immune to ________. To test this theory, Jenner experimented with his son. Matter from swinepox, ________, was injected into the boy's arm. This made the boy ________ to smallpox.

________, Jenner's great discovery, is now used to protect us against other diseases, among which are ________ and ________. Jenner is therefore one of the greatest ________ of mankind.

III. Complete each sentence begun in the left-hand column by choosing its proper ending from the right-hand column.

1. Vaccinov was	destroyed two million people in one year in Russia.
2. Minotaur was	can be prevented by vaccination.
3. Smallpox	prevents diseases from spreading.
4. Cowpox	the first child to be vaccinated in Russia.
5. Quarantine	a fabled monster of ancient times.
6. Typhoid	makes one immune to smallpox.

IV. Projects:

1. Why is the hottest part of a flame near the apex, rather than near the center?
2. When did the Black Death occur, and why was it so called?
3. What are some of the Pure Food Laws? Why were they passed?
4. How is one vaccinated?
5. How is a vaccine prepared?

V. " . . . You have erased from the calendar of human afflictions one of its greatest. Yours is the comfortable reflection that mankind can never forget that you have lived; future nations will know by history only that the loathsome smallpox has existed, and by you has been extirpated."

How would you prove that Jefferson, in this letter to Jenner, correctly judges Jenner's value to the world?

LOUIS PASTEUR

(Page 120)

I. Key Words:

pasteurization
germ
microbe
bacteria
rabies
culture
hydrophobia
epidemic

II. Complete this summary by choosing words for the blanks:

Louis Pasteur, the chemist, was born in ________ in the year 18__. Interested in the question why beer became ________ and why wine turned to ________, he discovered that these changes were due to ________ in the air. Later he also discovered that the silkworm disease, too, was due to ________.

When an ________ of chicken cholera broke out, Pasteur showed that this too had the same cause. This knowledge enabled him to prepare a ________ against the disease. He was given an opportunity to test his theory of vaccines with fifty ________. He proved that they could be made ________ from anthrax. He also developed a vaccine against ________.

The world remembers Pasteur by naming the process which keeps milk from being infected, ________. He was voted by the ________ of France to be the greatest Frenchman.

III. Choose the phrase that will make the statement true:

1. Pasteurization
   __ causes anthrax.
   __ makes one immune to disease.
   __ kills germs in milk.
   __ turns wine to vinegar.
2. Rabies
   __ gives one an intense desire for water.
   __ is a form of vaccination.
   __ is caused by dust in the air.
   __ is caused by biting a dog.
3. Anthrax
   __ is a silkworm disease.
   __ kills germs in milk.
   __ is caused by microbes.
   __ is a form of inoculation.
4. Dust
   __ causes chicken cholera.
   __ causes Pasteurization.
   __ is laden with microbes.
   __ gives one an intense desire for water.
5. To be immune to disease, one must
   __ have had anthrax.
   __ have had rabies.
   __ be vaccinated.
   __ be Pasteurized.

ROBERT KOCH
(PAGE 129)

I. Key Words:

globule	spores
test tube	tuberculosis
cotton wool	cholera
bacillus	typhoid
diphtheria	pneumonia
serum	bubonic plague

II. Complete the following summary by supplying words for the blanks:

Robert Koch, born in 18___, became a country doctor. Like ________ and ________ he spent much time with his microscope. In this way he discovered the germ of ________. In examining the blood of cows that died from this disease, he noticed that the microbes looked like ________ and ________. To study them, he made a ________ to keep the germs fixed. Thus the colony of ________ could be observed.

Koch found that the rods and threads can take the form of ________. He discovered that only an anthrax germ can cause ________, and only a ________ germ can cause typhoid. With the help of his assistants, he discovered the germs of eleven important diseases, among which are ________, ________ ________, ________, ________, and the ________ ________.

Koch was awarded the ________ Prize for medicine.

III. Complete each sentence begun in the left-hand column by choosing its proper ending from the right-hand column.

1. Spores	destroyed one-fourth of the world's population during the fourteenth century.
2. Anthrax germs	was awarded to Koch.
3. Black Death	can cause only anthrax.
4. Sunshine	grew readily in the serum Koch prepared.
5. Tuberculosis	carries the germ of sleeping-sickness.
6. The tsetse fly	is called the "Great White Plague."
7. Colonies of germs	always destroys anthrax bacilli.
8. The Nobel Prize	can withstand dry and cold weather.

IV. With the aid of an encyclopedia and other reference books prepare an essay on:

1. What a microbe looks like; its change to spores, etc.
2. The tsetse-fly.
3. What part of the world these diseases occur most frequently: cholera, bubonic plague, sleeping sickness, tuberculosis.

BARON JOSEPH LISTER

(PAGE 138)

I. Do you know these *key words?*

gangrene
carbolic acid
antiseptic
catgut
solution
pus
amputate
ligature

II. Joseph Lister was born in the year ______. As a doctor in the ______ Hospital, he was shocked to see so many patients die from hospital ______. He noticed that, if a patient came with a ______ limb and the outer skin had not been cut, the patient ______. But if the wound was an open one, ______ might set in. Lister, who studied the writings of ______ and followed his theories, therefore claimed that ______ entered the wound and caused putrefaction. To kill the microbes, he forged the first great antiseptic weapon, ______ ______. Lister successfully tested his theory by administering in his accident ward this ______ treatment.

In binding wounds due to fractures, Lister discovered that he need not leave long ______ hanging out of the wounds. He chose ______ as the best material for ligatures. The science of modern ______ is due to him. He died in the year ______.

III. Choose the phrase that will make the statement correct.

1. William Henley was
   ___ a surgeon.
   ___ the American ambassador.
   ___ a poet.
   ___ Lister's assistant.
2. A solution of carbolic acid
   ___ changes sugar to alcohol.
   ___ is an antiseptic for wounds.
   ___ causes hospital gangrene.
3. A ligature is
   ___ that which binds wounds.
   ___ an antiseptic.
   ___ blood poisoning.
   ___ an organ in the body.
4. Catgut was first used in medicine by
   ___ Paré.
   ___ Lister.
   ___ Pasteur.
   ___ William Henley.
5. Galen was a
   ___ Greek god.
   ___ Russian doctor.
   ___ Greek doctor.
   ___ French doctor.

IV. Projects.

1. Arrange these names in the order of their times, and give their dates: Ambroise Paré, Lister, Galen, Pasteur, Jenner, Harvey.
2. What is the "Oath of Esculapius" (or Æsculapius)?

GENERAL WILLIAM CRAWFORD GORGAS

(PAGE 149)

I. Key Words:

Stegomyia	dark-field microscope
delirium	wriggler
immune	host

II. Complete this summary by supplying words in the blank spaces:

William Crawford Gorgas was born in the year ________. As a child he wanted to be a ________. He finally became a ________. At the age of twenty-eight, he was stricken with ________ fever, but recovered and was therefore ________ to further attacks. In 1898, when Cuba, ridden with yellow fever, was ceded to the United States, General Gorgas was sent there to fight the new enemy, ________. He first ________ up Havana, but the ________ still gave battle.

Gorgas despaired until an old doctor told him to beware of the ________ mosquito. Gorgas decided to test this theory. Volunteers who permitted themselves to be bitten by these mosquitoes contracted the dread fever. This convinced Gorgas that the Stegomyia was the cause of the ________ and to fight it he had to study its habits. He found that its ________ first hatches into a ________ and this develops into a ________. The wriggler, although bred in the water, has to come to the ________ for air. Gorgas' great scheme was to pour ________ on the water, whereby the wrigglers ________.

He ordered that no container of water be left standing ________. In this way he exterminated ________ ________ completely in Havana. He was then sent by the ________ to ________, which he likewise purged of the fever. From ________ to this day not a single case has been contracted there.

III. Complete each sentence begun in the left-hand column by choosing its proper ending from the right-hand column.

1. Stegomyia	was found by Noguchi.
2. Santa Lucia	must be used to detect the yellow-fever germ.
3. Philadelphia	was used to cover all standing water in Havana.
4. Kerosene	is the name of the mosquito which carries yellow-fever germs.
5. Noguchi	is the name of a street in Ecuador.

6. The hydrophobia germ	was immune to yellow fever.
7. Gorgas	is an island where an army was destroyed by yellow fever.
8. A dark-field microscope	was the place where Noguchi worked on great problems.
9. Calle Noguchi	had a yellow-fever epidemic in 1793.
10. Rockefeller Institute	made yellow-fever vaccine.

IV. Problems.

1. How would you describe the rôle of the fly in spreading disease?
2. How would you describe the rôle of the mosquito in spreading disease?

V. One day a general, while walking with his little granddaughter, met Gorgas. The general introduced him: "This is General Gorgas, one of our great men."

"No, my child," said Gorgas, "not a great man; merely one who is trying to follow in the footsteps of a great man — Walter Reed."

Who was Walter Reed?

ELIE METCHNIKOFF

(Page 161)

I. Key Words:

Ephemeridae	phagocytes
starfish	tadpole
carmine	beriberi
cell	vitamin

II. Elie Metchnikoff, a native of ________, became, at the age of twenty-two, a ________ at the University of ________. For his studies on ________, ________ and ________, he became famous.

In 18__, Metchnikoff's experiment on a ________ showed him that certain body cells, the ________, fight against invading microbes. In his work at the ________ Institute, Metchnikoff developed his theory that old age comes only when ________ in our bodies grow weak, and he maintained that by proper feeding we can ________ life.

III. Complete each sentence begun in the left-hand column by choosing its proper ending from the right-hand column.

1. Kölliker	live for just a few hours.
2. Leipzig	is caused by eating polished rice.
3. Ephemeridae	was a great zoölogist.
4. Phagocytes	allowed Metchnikoff the use of a fine laboratory.
5. Beriberi	protects against scurvy.
6. Vitamin C	are white corpuscles.
7. Pasteur Institute	is the book center of Germany.

IV. Name three foods that contain each of the following: 1. Vitamin A; 2. Vitamin B; 3. Vitamin C.

CHARLES ROBERT DARWIN

(PAGE 170)

I. Key Words:

steamer duck	syphon (siphon)
halcyon	sea slug
octopus	naturalist

II. Complete the following summary by supplying words for the blanks:

Charles Darwin, whose father wanted him to be a ________, preferred to spend his time in collecting ________, so that when still a youth, he was recommended as the best-qualified ________ for a surveying tour around the ________ on the ship named ________. From his study of plants and ________ on that trip, Darwin evolved the theory of ________ selection, that the fittest are the ones who ________ in the struggle for ________. Though he worked on this theory for ________ years, he still did not think it ready for ________.

The same idea of natural selection struck another young Englishman, ________ ________ ________, who sent his ________ to ________ and asked him to announce it to the ________. Darwin was willing to step aside, and permit ________ to receive credit for the discovery, but Wallace was equally generous, and refused. This discovery ranks Darwin as the greatest ________ of modern times.

III. Complete each sentence begun in the left-hand column by choosing its proper ending from the right-hand column.

1. The *Beagle*	was the Greek name for the kingfisher.
2. Halcyon	were seen by Darwin on Galapagos Islands.
3. Octopus	are off the coast of Brazil.
4. Condors	is a cuttlefish.
5. Giant turtles	are huge vultures seen by Darwin at Tierra del Fuego.
6. St. Paul's Rocks	was a ship that made a five-year cruise around the earth.

IV. The book that impressed Darwin and Wallace so much was written by Thomas Malthus.

Consult an encyclopedia and give a few facts about Malthus.

GREGOR JOHANN MENDEL

(PAGE 181)

I. Key Words:

heredity
pollen
dominant
haemophilia
genetics
recessive

II. Complete the following summary by filling in the blanks:

Gregor Mendel's interest in ________ was aroused when he was yet a boy. He became a ________ of science in the town of ________, in Bohemia. While working in the monastery there, his interest in heredity led him to experiment with ________. For eight years he observed his garden of peas, and learned that tallness is a ________ trait, while shortness is a ________ trait. The peas also told him that green is a dominant color and yellow is a ________ color. More than ten ________ plants had to be grown before Mendel was sure of his theory.

We owe to him the new science of genetics, the study of ________ and ________.

III. Make two lists, one for dominant traits, and the other for recessive traits:

In peas: tallness
shortness
green
yellow
flowers ranging on the axis of the plant
flowers bunched together at the top

IV. Problems:

1. Tell how Mendel's theory is used practically by horse- and cattle-breeders.

2. Among the traits which Mendel selected for experiment in 1865 were:

(a). The difference in the form of ripe seeds.

The seeds are either round or roundish, with only a few shallow depressions (a dominant trait); or the seeds are irregularly angular and deeply wrinkled (a recessive trait).

(b). The difference in the form of ripe pods.

The pods are either simply inflated (a dominant trait), or they are deeply constricted between the seeds and are wrinkled (a recessive trait).

Trace the result of crossing the plants in both experiments for three generations.

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